Large Aircraft Interior Decontamination

Foreign Comparative Test Final Report

December 2000

Supporting the CINC's Uninterrupted Delivery Flow

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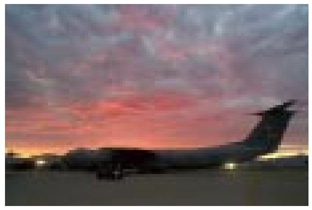
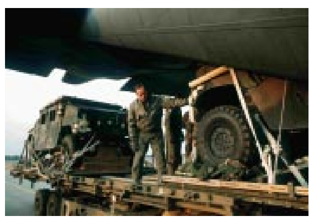


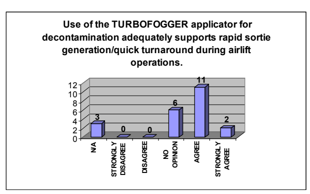
The Large Aircraft Interior Decontamination-Foreign Comparative Test evaluated the GD-5 decontaminant solution and applicators. The objective was to determine their potential to provide an interim decontamination capability of large frame aircraft from chemical warfare agents without affecting aircraft systems/components.

Phase I of the Foreign Comparative Test evaluation sought to verfiy GD-5's ability to neutralize selected chemical warfare agents and determine GD-5's corrosive effects. Both the DECOFOG IV and the TURBOFOGGER were used for this analysis. GD-5 did not corrode or impact sensitive equipment.

Phase II of the Foreign Comparative Test evaluation demonstrated operational utility of the TURBOFOGGER and GD-5 decontaminant solution during a dedicated field event. The TURBOFOGGER proved to have utility in field operations.



Task 1: *GD-5 proved to be a better nerve than blister agent decontaminant.*
Task 2: *GD-5 corrosive effects rated excellent by National Association of Corrosion Engineers.*
Task 3: *TURBOFOGGER capable of dispensing sufficient decontaminant to neutralize chemcial warfare agents.*



Laboratory testing of the GD-5 decontaminant solution indicates that it neither excessively corrodes nor impacts sensitive equipment. The ambient aerosolized GD-5 decontaminant solution did not prove to be better than currently fielded decontaminants. The TURBOFOGGER applicator proved to have military utility.

Further examination of the GD-5 decontaminant solution in a thermal application is needed to determine its ability to expeditiously support rapid aircraft interior and cargo decontamination.

APPENDICES

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LIST OF ACRONYMS

ACADA	Automatic Chemical Agent Detector Alarm
AED	Assessment Execution Document
AFB	Air Force Base
AFOTEC	Air Force Operational Test and Evaluation Center
AFRL	Air Force Research Laboratory
AMARC	Aerospace Maintenance And Regeneration Center
AMC	Air Mobility Command
ASTM	American Society for Testing and Materials
CAM	Chemical Agent Monitor
CASCAD	Canadian Aqueous System for Chemical Biological Agent Decontamination
CINC	Commander in Chief
CONOPS	Concept of Operations
COTS	Commercial Off-The-Shelf
CP	Counter Proliferation
CW	Chemical Warfare
DEM	Diethyl Malonate, a chemical nerve agent simulant
Det 1	Detachment 1
DHP	Digital Hydrocarbon Probe
DoD	Department of Defense
DRES	Defence Research Establishment Suffield
ERDEC	Edgewood Research, Development and Engineering Center
FCT	Foreign Comparative Test
GC	Gas Chromatograph
GD	Soman, a nerve agent
HD	Distilled Mustard, a blister agent
HQ	Headquarters
HSW	Human Systems Wing
IDLH	Immediately Dangerous to Life and Health
JSMG	Joint Service Material Group
JSSED	Joint Service Sensitive Equipment Decontamination
KPP	Key Performance Parameter

LAID	Large Aircraft Interior Decontamination
LC	Liquid Chromatograph
LFA	Large Frame Aircraft
MES	Methyl Salicylate, an emulator of Mustard Gas
MOE	Measure of Effectiveness
MOPP	Mission Oriented Protective Posture
MS	Mass Spectrometer
MSDS	Material Safety Data Sheet
MUA	Military Utility Assessment
NACE	National Association of Corrosion Engineers
NATO	North Atlantic Treaty Organization
NDI	Non-developmental Item
ORD	Operational Requirements Document
OSHA	Occupational Safety & Health Administration
OWR	Odenwald-Werke Rittersbach, a German company
ppm	Parts per million
psi	Parts per square inch
QSTAG	Quadripartite Standardization Agreement
RCM	Requirements Correlation Matrix
T&E	Test and Evaluation
TPFDD	Time-Phased Force and Deployment Data
USAF	United States Air Force
USMC	United States Marine Corps
VX	O-ethyl-S-(2-iisopropylaminoethyl) methyl phosphonothiolate, a nerve agent

PREFACE

The scope of this Large Aircraft Interior – Decontamination Foreign Comparative Test (LAID-FCT) was limited to the demonstration of the potential viability of a new concept of operations using a foreign non-developmental item (NDI) technology. To address the viability of the decontaminant under evaluation, engineering level data were collected, assessed, and reported on the decontaminant's effectiveness in neutralizing selected chemical agents, as well as on the short and medium term corrosive effects of the decontaminant. There was no attempt during the demonstration to gather statistically significant engineering level data on the decontamination system's performance. Further, due to the short duration of the demonstration, the operational suitability characteristics of the system for deployment were not fully assessed. Consistent with FCT program guidance, the format of the field demonstration was not designed to provide enough data to accurately determine system reliability. However, system malfunctions and other suitability problems were noted as they arose. Other deployabilty questions, such as the safety of using the decontamination system simultaneously with other aircraft ground servicing activities, were not answered under the limited demonstration scope.

No classified information was used to generate, or is included in, this final report. In accordance with FCT program guidance, this report will be submitted to the project sponsor for further disposition. Any restrictions upon the dissemination of this report, or any classification of the information contained herein, are at the discretion of the sponsoring agency.

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EXECUTIVE SUMMARY

Detachment 1 (Det 1), Air Force Operational Test and Evaluation Center (AFOTEC) assessed the effectiveness of the GD-5 decontaminant (hereafter referred to as GD-5) and its two associated applicators in neutralizing selected chemical warfare agents, as well as the system's capability to decontaminate large frame aircraft (LFA) to the "operational level."

At the operational level, according to United States Air Force (USAF) disaster preparedness procedures, chemical agent contact or transfer hazard is minimized while operations are sustained. In other words, the decontamination goal is to neutralize the chemical agent to a degree that aircrews and other personnel can do their job without risking harmful effects from the remaining agent.

Det 1 conducted this demonstration as an FCT program qualification test and structured it as a military utility assessment (MUA). MUA protocols provide a mechanism for Det 1 to maintain its independence as an operational test agency and to produce information consistent with USAF acquisition policies. With regard to the policies governing the operational test and evaluation of systems being acquired by the USAF, rigor introduced into the MUA format was not mandated by the FCT program. However, implementation of the MUA format ensured both the integrity of data collected and future usability of test results deemed vital in USAF acquisition strategies.

The test/assessment designed by Det 1 included two distinct phases. Phase I testing measured GD-5's decontamination effectiveness against chemical warfare agents, corrosiveness on aircraft materials, and impacts to sensitive equipment. Phase II testing focused on field decontamination effectiveness using the TURBOFOGGER applicator and GD-5 in an LFA. In both phases of the FCT, tasks were established and measures of effectiveness (MOE) tested in order to assess the performance of GD-5 and its applicators. This assessment was designed to verify the vendor's advertised product performance and to provide the Air Mobility Command (AMC) with credible information about the utility of GD-5 and its applicators for operational level decontamination of LFA and cargo. This report will provide AMC with a basis to make meaningful procurement decisions concerning GD-5, the TURBOFOGGER, and the DECOFOG IV.

Test Results

- *Aerosolized GD-5 is not corrosive.*
- *Aerosolized GD-5 does not significantly impact sensitive equipment.*
- *High concentrations of aerosolized GD-5 to chemical warfare agent are needed to affect agent neutralization.*
- *TURBOFOGGER applicator has utility and is capable of dispensing high quantities of decontaminant.*

Test Results

AMC identified three critical tasks which needed to be addressed by Det 1 in order to provide sufficient data to determine if GD-5 and its applicators have military utility for LFA decontamination. Each task was then subdivided into MOEs. The MOEs were created to determine how well GD-5 and its applicators fulfilled a particular aspect of the associated task. Each MOE was rated and then aggregated to determine the overall rating of the associated task. Table 1 depicts the overall rating assigned to each task accomplished during the FCT. (See Appendices B, C, and D for detailed MOE ratings). The qualification test conducted and executed by Det 1 sought to verify and validate vendor claims. Table 2 presents findings in comparison to vendor claims as validated by Det 1 during this FCT. See Table 3 for consumer reports style rating key.

Table 1. Task Level FCT Test Results: MOE results were aggregated to determine task level results.

Task 1		Application of GD-5 using fogging techniques neutralizes chemical warfare agents to the operational level.
Task 2		Application of GD-5 using fogging techniques decontaminates LFA interiors without corroding sensitive equipment or creating hazards.
Task 3		Application of GD-5 using fogging techniques supports sortie generation and rapid aircraft turnaround consistent with applicable chemical warfare environment operational flows.

Table 2. Performance vs. Vendor Claims: Verification of vendor claims was a primary purpose of the FCT.

Effectiveness Against Live Agents		Anti-Corrosive Properties		Hardware Usability		Environmental Considerations		Safety	
HD		Copper		Size		Disposal		Inhalation	NR
GD		Brass		Weight:		Safe		Skin Contact	NR
VX		Other Metals		Empty		HazMat			
		Acrylic		Full		HazWaste			

HD - Distilled Mustard, a blister agent
GD - Soman, a nerve agent
VX - O-ethyl-S-(2-iisopropylaminoethyl) methyl phosphonothiolate, a nerve agent

Findings based on:

- French Testing
- Edgewood Research, Development and Engineering Center (ERDEC) Testing
- Company Brochures
- Material Safety Data Sheets (MSDS) GD-5 Decontamination System Performance Summary
- Defence Research Establishment at Suffield (DRES) Liquid Phase Testing

Table 3. Consumer Reports Rating Key: A consumer reports style rating is assigned to each Task and MOE.

▲	–	Demonstrated utility
▲	–	Demonstrated utility; improvements recommended
△	–	No utility beyond currently fielded capabilities
▼	–	Potential utility; <u>not</u> deployable now; significant improvements required
▼	–	No utility demonstrated
I/D	–	Insufficient data for a conclusive rating
NR	–	Not rated

Recommendations

Equipment Recommendations

- The power supply should be self-contained. If such a modification is not feasible, then the equipment must be modified to also operate on power most commonly available in LFA (such as 110 volt, 60 cycle, single phase).
- The solution tank cap should be modified to preclude difficulties in securing it while in mission oriented protective posture (MOPP) gear.
- The fog tap switch used to set droplet size for fog generation should be modified to correct problems noted during the MUA field demonstration. The fog tap switch is difficult to see and can easily be moved from desired setting.

Follow-on Test Recommendations

- Evaluate GD-5 and applicators in complex aerosol environments
- Evaluate GD-5 thermal aerosol application on chemical warfare agents
- Evaluate GD-5 aerosol applications during concurrent aircraft operations

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SECTION 1
LAID-FCT TEST OVERVIEW

This final report describes Det 1's assessment for supporting the FCT of off-the-shelf German technologies for use in LAID (Figure 1). This FCT was designed as a qualification test based on guidance outlined in the Department of Defense's (DoD) document, *The Foreign Comparative Testing Program Handbook*.[1]

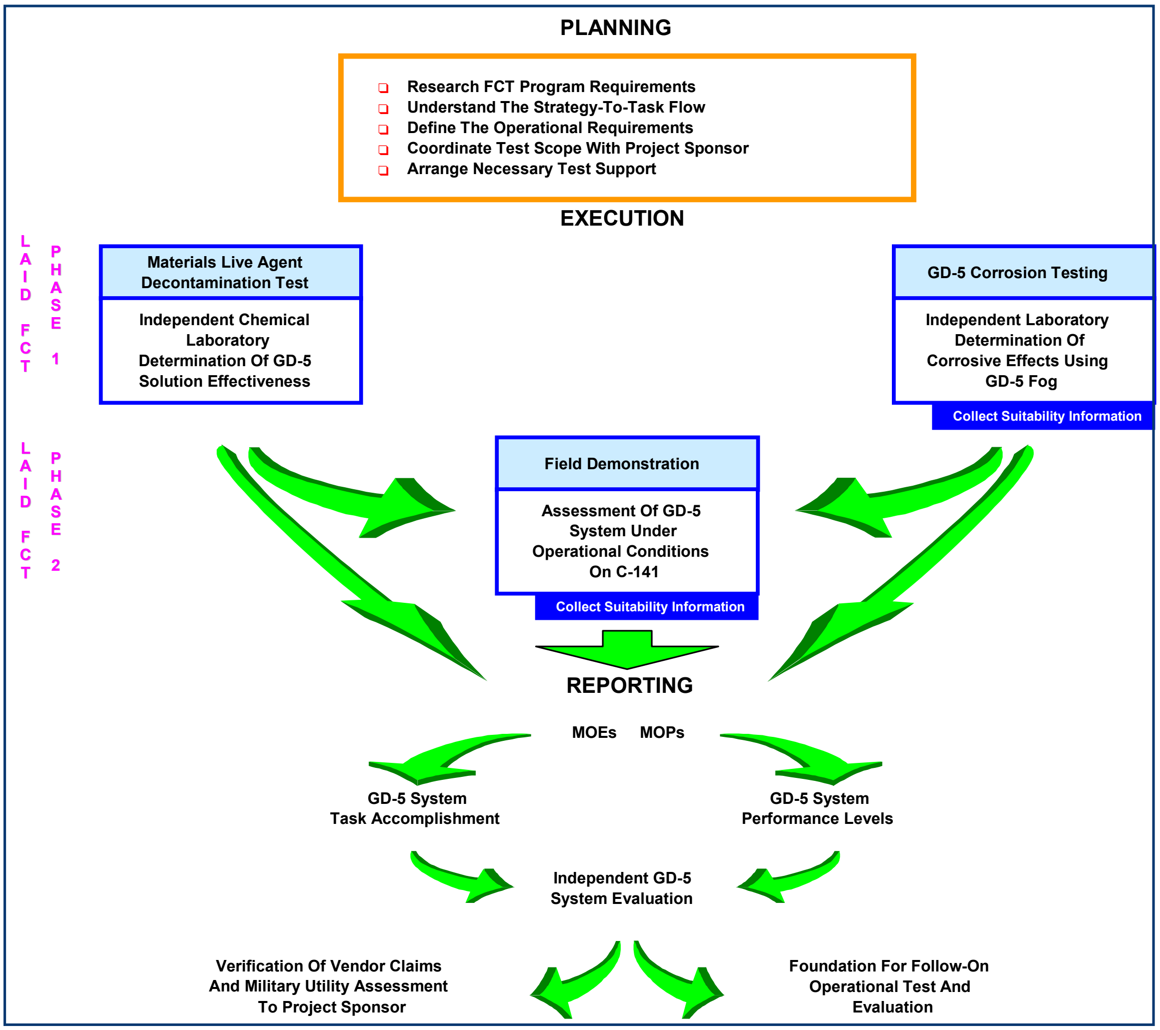

Figure 1. The FCT Test Logic: The FCT was conducted in two phases to verify vendor claims and to assess the system's military utility.

[1] The Foreign Comparative Testing Program Handbook, 5 Aug 99, Chapter 5, Page 5-6.

Being a qualification test, this FCT sought to verify that the German-made GD-5 meets the vendor's claims for its effectiveness and use in decontaminating chemical warfare agents.

While not specifically called for by FCT protocols, this test was structured as an MUA. This approach to test planning and reporting allowed Det 1 to apply appropriate rigor to the FCT, thereby ensuring the results answer key questions for the system user. Another benefit of adhering to the utility assessment rigor was that the results of the effort would provide sound foundational information for future tests.

Since Det 1's effort was simultaneously an FCT program qualification test and a military utility assessment, the terms "test" and "assessment" are used interchangeably throughout the remainder of this report. Based on the results shown in this report, the System Program Office responsible for fielding Air Force decontamination equipment (311 Human Systems Wing [HSW]/YACN) will formulate an acquisition recommendation. Ultimately, the FCT's sponsor, AMC, will make a procurement decision.

The LAID-FCT was conducted in two phases (see Figure 1). Phase I of the assessment consisted of laboratory tests that supported Det 1's field work in the test's second phase. Phase II of the test was a dedicated field demonstration and system verification at the Aerospace Maintenance and Regeneration Center (AMARC) at Davis-Monthan Air Force Base (AFB), in Tucson, Arizona.

Figure 2. Interior Decontamination: GD-5 was developed to be a non-corrosive, nonconductive, and environmentally safe way of combating chemical and biological contamination.

The LAID-FCT was conducted to assess the capability of both a chemical decontaminant and its applicators to meet a critical Air Force need.[2] This test addressed the issues of chemical decontamination on both materials and equipment and examined decontamination procedures using specific solution applicators. The certified chemical laboratory phase of the test used chemical agents and simulants, while the field phase used only a simulant, to address both quantitative and qualitative test objectives.

Technology developed by Odenwald-Werke Rittersbach (OWR), a German company, was evaluated during this FCT (Figure 2).

[2] DoD Annual Report To Congress, The Foreign Comparative Testing Program, Fiscal Year 1999, Feb 2000, Projects Selected, Page 47.

The following items were assessed for their capabilities in LAID:

- GD-5, a chemical decontaminant
- the DECOFOG IV applicator
- the TURBOFOGGER applicator

Phase I of this FCT was further subdivided to address specific issues associated with the decontamination process. Det 1 selected two agencies located in Alberta, Canada, to serve as independent laboratories to meet the data requirements of Phase I. These agencies, DRES and Dycor Technologies, Ltd., of Alberta, Canada, sought to verify the effectiveness of chemical agent decomposition and corrosive effects of GD-5 in accordance with test plans approved by Det 1 [Assessment Execution Document (AED), June 2000, Appendices B and C].

Phase II was conducted by Det 1. Supporting laboratory personnel augmented Det 1 in the field during Phase II testing to ensure continuity in test procedures relative to the decontaminant's corrosive effects and to provide technical assistance in utilizing the equipment under test. Operational units also supported Det 1 during the field test phase of this FCT. These units had the opportunity to perform decontamination operations on a C-141 Starlifter (hereafter referred to as C-141) which is representative of all large frame transport aircraft in use by American forces today, prior to its decommissioning. Decontamination operations were accomplished in accordance with the AMC concept of operations (CONOPS) for this activity. Aircrew and qualified maintenance personnel represented operational users of LFA for the purpose of this assessment. Units participating in this test included:

- 437th Airlift Wing USAF, Charleston AFB, South Carolina
- 355th Civil Engineering Squadron, USAF, Davis-Monthan AFB, Arizona
- 2nd Marine Airlift Wing, United States Marine Corps (USMC), Cherry Point Marine Corps Air Station, North Carolina

Background

The FCT

The FCT program was instituted to test and evaluate foreign NDI and equipment that demonstrate potential to satisfy user requirements. Mandated by Congress in 1989 under Title 10, United States Code, the program supports national policy of encouraging international arms cooperation while reducing overall DoD acquisition costs. The FCT program is consistent with DoD Directive 5000.1 and current emphasis on acquisition reform, in that it places first priority on providing an available material solution to satisfy validated requirements or correct mission area shortfalls. The program is funded under the DoD Research Development Test and Evaluation 0400 Budget.[3]

Under FCT program tenets, the individual project's sponsor (a military service or the U.S. Special Operations Command) is ultimately responsible for all aspects of the FCT, including test and evaluation (T&E). The T&E plan developed for the FCT was based on defined requirements, such as those contained in an Operational Requirements Document (ORD), and should:

- Implement cost effective T&E
- Recognize the NDI nature of FCT items
- Identify key performance parameters and address them early in testing phases
- Consider a phased T&E approach
- Include all credible items

Vendor participation in test planning is encouraged under the FCT program. For those projects that are being tested for procurement, one of two types of tests should be planned under the FCT program. The first type of possible test is the comparative test, where multiple items are evaluated against each other. The second type of FCT test in this category, the type being executed under this plan, is the qualification test, where a vendor's claims for the product are verified or validated.[4]

The LAID project sponsor, AMC, sought support for this FCT effort through established Air Force acquisition processes and contacted the Human Systems Program Office, 311 HSW/YACN. YACN formulated the project proposal and assisted AMC, through Headquarters (HQ) Air Force, in gaining Congressional approval for the LAID-FCT. Det 1 complied with FCT program guidance in conducting the qualification test for LAID. As an independent test agency and using the format of a military utility assessment, Det 1 sought to verify the vendor's claims for its products and, at the same time, measured the system's performance against operational requirements.

To verify vendor claims, Det 1 researched the vendor's publications and generated a list of measurable performance parameters for use during this FCT qualification test (AED, June 2000, Appendix K). Each of the developed parameters is comprised of two elements: a capability (or characteristic) and a criterion which establishes the level of performance associated with that capability. Det 1 used this format to document vendor claims to facilitate comparison of data, since DoD ORDs use a similar format.

[3] The Foreign Comparative Testing Program Handbook, 5 Aug 99, Chapter 1.
[4] IBID, Chapter 5.

In the aftermath of the Gulf War, the need to counter the effects of chemical attacks, which could degrade U.S. combat and combat support operations, gained renewed emphasis. As the requisite USAF strategies for operating in chemically or biologically contaminated environments became available, AMC began restructuring its cargo movement and handling procedures, as well as its CONOPS, to standardize airlift operations in a contaminated environment.

The *USAF Chemical Warfare Concept of Operations* defines two predominant contamination threats to LFA (more commonly referred to as cargo aircraft):[5]

- the aircraft being left outside and unprotected (i.e., with doors, hatches, and/or ramps open) at the time of a chemical attack
- contaminated cargo being allowed onto the aircraft

This Air Force guidance further specifies that once an aircraft is contaminated it will normally be decontaminated to the "operational level or above" before returning to an uncontaminated airfield. At the operational level, according to USAF disaster preparedness procedures, chemical agent contact or transfer hazard is minimized while operations are sustained. In other words, the decontamination goal is to neutralize the chemical agent to a degree that aircrews and other personnel can do their job without risking harmful effects from the remaining agent. The called-for decontamination is to take place at the dirty airfield (or origination point), in flight, or at a location specifically designated for decontamination activities.[6]

The definition of decontamination, approved by all U.S. forces, and used to evaluate GD-5 performance during this assessment, is: *a reduction in the concentration or neutralization of the effects of a chemical agent present on resources to below miosis or incapacitation levels*. Below the point where miosis occurs, aircrews and other personnel can function without risking harmful effects from a chemical agent. This level of contamination (i.e., below miosis) thus permits unrestricted operations to continue.

Timeliness of the decontamination activities is another key factor in the USAF CONOPS for airlift operations in a hostile chemical environment.[7] During a contingency, AMC supports the operation's Commander in Chief's (CINC) needs according to a schedule known as

[5] USAF Chemical Warfare Concept of Operations, Appendix 3, Paragraph 11.G.App3.3.

[6] IBID, Paragraph 11.G.App3.6.3.3.

[7] IBID, Paragraph 11.G.App3.6.1.

Time-Phased Force and Deployment Data (TPFDD).[8] Timely decontamination minimizes impacts to mission operations, thus ensuring an uninterrupted delivery flow to the supported CINC.

Implementation of the Air Force CONOPS is detailed in AMC's 1999 plan *Air Mobility in a Chemical and Biological Environment*. Recognizing the same likely threats to airlift operations as identified by USAF planners, AMC also notes that contamination could be introduced into the aircraft through terrorist action[9] (such as an aerosol device with a delayed action fuse) following cargo loading. While the contingency of such action must be dealt with, it presents the same operational impacts as the loading of contaminated cargo cited in the USAF CONOPS. Since this AMC guidance is procedural in nature, it necessarily includes only decontamination capabilities currently available to achieve the operational level of risk.

Current aircraft interior decontamination processes outlined by AMC include water or bleach washes, protracted aeration (in open air or using forced hot air) and, in some instances, the use of absorbent towelettes or pads to clean affected cargo and aircraft surfaces.[10] The use of aqueous solutions for cleaning aircraft interior surfaces has limited utility due to their inherent corrosive effects. Considering the surface area that would need decontamination following a chemical event occurring after loading, these processes would not adequately meet the time constraints dictated by delivery flows in contingency operations. What's more, the increased work time to accomplish this laborious effort, required by decontamination crews in protective gear (1.2 to 5 times normal work time for a given task[11]), would push the actual delivery flow to unacceptably long time periods. Thus, the current AMC procedures for decontaminating aircraft interiors and cargo to the operational level fall short of accomplishing that task as it is laid out in the USAF CONOPS.

In its plan for *Air Mobility in a Chemical and Biological Environment,* AMC also outlines its responsibilities to identify and test decontamination procedures that can better fulfill the command's mission requirements.[12] Being unable to find any technologies within the U.S. to permit rapid decontamination of LFA interiors and cargo to the operational level, AMC identified OWR's GD-5 and its applicators as having potential to fulfill this mission area need. AMC requested this FCT in order to establish the actual utility of GD-5 and its applicators

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[8] Air Mobility Operations In a Chemical and Biological Environment, 9 Feb 99, Paragraph 1.a.
[9] Air Mobility Operations In a Chemical and Biological Environment, 9 Feb 99, Paragraph 1.a.(1)(a)
[10] IBID, Annex C, Appendices 4 and 5
[11] IBID, Table A8.1
[12] IBID, Paragraph 5.a.

for such decontamination. Det 1 was selected as the test organization to conduct the live agent and MUA portion of this FCT.

Figure 3. Loading for Contingency Operations: TPFDD loads for the C-141 and other cargo aircraft include both palletized cargo and rolling stock.

LAID Operational Requirements

The need to decontaminate LFA and other sensitive equipment led American uniformed forces to work together in documenting the requisite capabilities for such operations (Figure 3). Operational requirements applicable to LAID are published in the *Operational Requirements Document for a Joint Service Sensitive Equipment Decontamination* (JSSED ORD).[13]

Not all elements of the JSSED ORD requirements were answered under the limited scope of this FCT qualification test/MUA. AMC and 311 HSW/YACN approved the scope of this test in order to address the key issues needed for a procurement decision under the FCT program.

The required capabilities for a system performing LAID are presented in a Requirements Summation Matrix contained in Appendix F. This FCT qualification test directly addressed issues associated with the following subset of the requirements:

- Neutralize chemical agent
- Decontaminate during ground and in-flight operations
- Produce no toxic, corrosive, or non-disposable residue or vapors during decontamination
- Have no adverse effects on aircraft systems or surfaces
- Be less environmentally hazardous than current decontaminants
- Decontaminate an unloaded or loaded cargo compartment within one hour
- Operate continuously for one hour without resupply
- Fit in the crew entrance door
- Be man-portable with a maximum weight of 100 pounds
- Be non-aqueous
- Be ready to use without decontaminant processing or testing
- Use a biodegradable, nonflammable decontaminant
- Use an easily refilled/recharged, non-hazardous applicator
- Have no adverse effects on MOPP gear

[13] Operational Requirements Document for a Joint Service Sensitive Equipment Decontamination, (JTD J5-002-II) MS II Revision, 17 Aug 99, Paragraph 1.c.(2).

Technology Descriptions

The off-the-shelf German decontamination system under assessment during this FCT includes the GD-5 and two applicators designed for dispensing the solution. For applications such as the decontamination of LFA interiors and cargo, the decontamination applicators are designed to create a fog, similar to naturally occurring fog, which is able to penetrate into very small areas. As in the case of natural fog, the GD-5 fog leaves behind a thin coating of the solution on all it touches. This film is intended to neutralize chemical agents within 30 minutes. Though thorough decontamination techniques would call for removal of residual decontaminant and by-products resulting from the decontaminant's interaction with an agent, this process is not deemed mandatory by the solution developer to lower contamination to acceptable levels. Use of GD-5 in this manner is alleged to be safe for all materials found in LFA, as well as for direct application to electronics and other sensitive equipment. The system is designed for use in decontaminating vehicles, aircraft, and equipment operating in a chemical/biological warfare environment. Emergency use of GD-5 applied directly to human skin for decontamination is purportedly safe according to the developer, though not assessed by Det 1 under this FCT.

GD-5 Decontaminant Solution

The GD-5 solution is a broad-spectrum, rapid acting, non-aqueous chemical/biological decontaminant liquid. The solution is a mixture of amine-alcoholates and a nonionic surfactant. It neutralizes chemical agents through a process known as nucleophilic substitution. The speed with which this substitution takes place is enhanced by the solution's strong basicity. The solution has an advertised 10-year shelf life. In addition to use as a fog, GD-5 may be sprayed or swabbed onto affected areas.

Figure 4. DECOFOG IV Applicator: Due to the high temperatures associated with the DECOFOG IV, the applicator was only used during the Corrosion Test.

DECOFOG IV

The DECOFOG IV applicator (Figure 4) can be transported and used by a single operator. The unit weighs seven kilograms when empty. Its fuel tank has a two-liter capacity and its detachable solution tank holds nine liters. Its gasoline-powered motor has an electronic ignition powered by four onboard 1.5 volt batteries. Adjustable nozzle sizes allow the unit to dispense solution at a flow rate between 0 and 25 liters per hour. The DECOFOG IV is deemed a thermal applicator, since it heats the dispensed solution to over 1100 degrees Fahrenheit before disbursement. The applicator is equipped with a dual cooling sleeve diffuser to prevent inflicting accidental burns. Due to the high temperatures generated at the tip of the discharge barrel, which caused safety concerns, the DECOFOG IV applicator was only used during the GD-5 corrosion test.

TURBOFOGGER

Figure 5. TURBOFOGGER Applicator: The TURBOFOGGER, which applies unheated GD-5 solution, was used in both the corrosion test and in the field demonstration.

The TURBOFOGGER (Figure 5) can also be transported and used by a single operator. The unit is manufactured with an electric motor that uses 220 volt, 50 cycle alternating current from an external source. For this FCT a TURBOFOGGER unit was externally modified to operate on 115 volt, 60 cycle alternating current. It has a solution capacity of six liters and can be adjusted for a flow rate between 0 and 48 liters per hour. The TURBOFOGGER, which is a pneumatic cold fogging unit and applies unheated GD-5, was used in both the GD-5 corrosion test and in the field demonstration.

Assessment Scope and Structure

The Air Force, at AMC's request, submitted the LAID project for approval under the FCT program. Thus, Det 1 sought to verify vendor claims for GD-5 and its applicators and assessed its military utility relative only to LFA. AMC and 311 HSW/YACN approved the scope of the planned test as addressing the issues which need to be answered prior to their procurement decision under the FCT program.

This FCT is, as indicated by its name, a comparative test. Specifically, this assessment compared the observed performance of GD-5 decontaminant fogging techniques to the vendor's claims for the process. This qualification test was designed to compare the effectiveness of GD-5 and its applicators to a previously established baseline for decontaminating DoD assets. Thus, this FCT was designed to test the effectiveness of GD-5 in decontaminating the following three chemical agents: Distilled Mustard (HD), Soman (GD), and U.S. nerve agent (VX). These agents were selected by Det 1 as representative agents for the purpose of this FCT. In addition to testing with the selected chemical warfare agents, the simulants Methyl Salicylate (MES) and Diethyl Malonate (DEM) were used to perform certain aspects of the testing.

Corrosion testing conducted by Dycor Technologies, Ltd., addressed the effects of applying only the GD-5 solution to test articles. By-products resulting from application of GD-5 to chemical agents or simulants were not analyzed under this FCT.

The objective of this FCT qualification test/MUA was to demonstrate the capability of a possible off-the-shelf solution to remove chemical agents from representative aircraft and cargo materials. Removal of such agents will allow decontamination of airlift assets to the operational level and thus support USAF strategy to maintain contingency operations delivery flows in a chemical warfare environment.

The two phases of the test/utility assessment together address three main tasks which need to be accomplished by GD-5 chemical decontamination (Table 4) if this system is to be a viable option for improving AMC's airlift operations in a chemical environment. Det 1 aligned each of the parameters it intended to evaluate with the task that must be done by a successful decontamination system. Each of the three tasks assigned to GD-5 and its applicators was subdivided into MOEs functionally related to that task. The MOEs for this utility assessment were created to determine how well GD-5 and its applicators fulfilled a particular aspect of a task.

Table 4. Tasks Assessed: AMC provided three areas of primary focus for the FCT.

Task 1	Application of GD-5 using fogging techniques neutralizes chemical warfare agents to the operational level.
Task 2	Application of GD-5 using fogging techniques decontaminates LFA interiors without corroding sensitive equipment or creating hazards.
Task 3	Application of GD-5 using fogging techniques supports sortie generation and rapid aircraft turnaround consistent with applicable chemical warfare environment operational flows.

During this FCT, materials which comprise both elements of the aircraft interior and items normally onloaded as cargo or with cargo were subjected to three different chemical warfare agents (HD, GD, VX) during laboratory testing for a quantitative assessment of the GD-5 decontaminant. FCT laboratory testing conducted during Phase I of the test was accomplished in accordance with established international safety and standardization protocols for agent test penetration and materials decontaminability. Phase II of the test was conducted as an outdoor field demonstration at Davis-Monthan AFB.

Test Limitations and Constraints

The following list summarizes the limitations and constraints impacting conduct of the LAID-FCT field demonstration:

- No safety information was available on by-products of GD-5 interaction with agents or simulants.

- Due to the short duration of the field demonstration, no attempt was made to gather statistically significant engineering level data on GD-5's or the TURBOFOGGER's performance.
- Field demonstration's short duration precluded full identification of operational suitability characteristics (i.e., reliability, maintainability, transportability, etc.) of GD-5 or the TURBOFOGGER for deployment.
- Safety of using GD-5 or its associated applicators simultaneously with other aircraft ground-servicing operations was not investigated by conducting such activities (collected representative user opinions of GD-5 and the TURBOFOGGER only). DECOFOG IV was not evaluated during the field demonstration due to its tendency to produce open flame.
- A partially decommissioned aircraft was used for field testing (Figure 6).
    - mock cargo load aboard the C-141
    - no sorties generated

Figure 6. The Test Bed: AMARC provided a C-141 from its decommissioning flow as a test platform for the field demonstration.

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SECTION 2
LABORATORY VERIFICATION TESTING

PHASE I TEST OVERVIEW AND RESULTS

OVERVIEW

The initial phase of the FCT evaluation consisted of laboratory evaluations of GD-5 on live CW agents (both liquid and aerosolized) and corrosion impacts to aircraft materials and sensitive equipment.

The following tasks were designed to answer the questions of live agent neutralization and impacts to aircraft component materials and sensitive equipment.

Task 1: Application of GD-5 using fogging techniques neutralizes chemical warfare agents to the operational level.

Inclusion of this task in the LAID-FCT allowed the evaluation team to assess the effectiveness of the GD-5 solution in neutralizing chemical agents recognized as a threat to DoD assets. It answered the basic question of whether or not decontamination of live chemical warfare agents can be successful using GD-5. Due to the scope of this utility assessment, GD-5 was tested on only three such agents: HD, GD, and VX. Neutralization of the chemical agent simulants DEM and MES were also tested to establish correlation between laboratory and field decontamination tests. GD-5's effectiveness was then assessed relative to established baselines for successful chemical decontamination.

The following operational requirements were directly addressed in the analysis of this task:

- Chemical agent neutralization (accomplished for three chemical agents and two simulants)
- Decontamination during ground and in-flight operations

Task 2: Application of GD-5 using fogging techniques decontaminates LFA interiors without corroding sensitive equipment or creating hazards.

The threat addressed during this FCT was that the interior of an LFA and its cargo could become chemically contaminated. In this event, materials and equipment located in the aircraft, whether part of the plane or part of the cargo, will be in direct contact with the airborne chemical agent. Successful decontamination of this material and equipment means that GD-5 will also be in direct contact with these items. Thus, GD-5 must not corrode or otherwise degrade the use of the material and equipment it touches. Analysis of GD-5's effects on items representing both aircraft components and cargo elements determined the solution's ability to satisfy this task.

The following operational requirements for the decontamination were directly addressed in the analysis of this task:

- Produce no toxic, corrosive, or non-disposable residue or vapors during decontamination
- Have no adverse effects on aircraft systems or surfaces
- Be non-aqueous
- Use a biodegradable, nonflammable decontaminant
- Be less environmentally hazardous than current decontaminants

Live Agent Testing

GD-5 is an organic liquid decontaminant that is reputed to be effective against all liquid persistent chemical warfare (CW) agents. GD-5's principal effective components are ethanolamine and potassium hydroxide. OWR, the manufacture of GD-5, has proposed its decontaminant as having potential use for aircraft decontamination. The concept behind using GD-5 as an aircraft decontaminant is that it can be applied to aircraft interiors as an aerosol mist or fog dispensed via a company-owned applicator. In theory, the GD-5 liquid would (as a mist) settle onto exposed surfaces and react with and destroy any CW agent present. To accomplish this task, fogged GD-5 would be left on the aircraft surfaces for a period of time without physical scrubbing or mechanical mixing of the CW agent with the decontaminant as would normally be required by other fielded decontaminant systems such as DS2, German Emulsion, Canadian Aqueous System for Chemical Biological Agent Decontamination (CASCAD) and BX-24.

The objectives of the laboratory tests were two-fold: verify vendor claims for decontamination of HD, GD, and VX under similar testing protocols and determine the effectiveness of the decontaminant when applied as an aerosol to the same three CW agents.

Liquid phased testing was accomplished in a Liquid Chromatograph-Mass Spectrometer (LC-MS), Gibson Model 231-401, Auto Sampling Injector system equipped with a Model 401 Dilutor in order to verify vendor claims that GD-5 was an effective decontaminant on HD, GD, and VX. Decontamination efficacy testing was accomplished in a Varian gas chromatograph (GC) using a factory installed and qualified preconcentration sampling system to determine the effectiveness of GD-5 when applied as an aerosol versus HD, GD, and VX. Efficacy testing and methodologies followed the Quadripartite Standardization Agreement (QSTAG) 747 protocol defined in the minutes of The Technical Cooperation Program Action Group 30, which have been incorporated into the North Atlantic Treaty Organization (NATO) D/102 (Panel 7 Working Group 3) draft tiptych on equipment decontamination. In this sampling methodology a gas stream (of air or nitrogen) is passed through the sample cell containing the CW agent and decontaminant. This gas stream, which has the evolved CW agent vapor from the test coupon, is then captured onto a preconcentration absorbent. As a result, the total quantity of the CW agent in the sample stream passing through the GC system over a prolonged period of time can be collected and then thermally deposited onto the GC column. This procedure allows production of a quantitative chromatogram corresponding to the total amount of CW agent recovered in a specified absorption period.

Liquid Phase Test Results

With respect to the reactivity of GD-5, it is a fast reacting decontaminant in the liquid phase provided that sufficient ratio of GD-5 to CW agent is maintained. For example, in the case of VX, on a weight-to-weight basis, at a ratio of 18:1 GD-5 yields a half-life in liquid solution of just over one minute. By contrast, a ratio of 4.7:1 results in approximately 16 percent residual agent (after normalization for agent purity) remaining after 87 minutes. Clearly, in the liquid phase, a significant excess of decontaminant is required to eliminate VX in a reasonable time frame. In the cases of HD and GD, elevated ratios of GD-5 to agent are also needed for rapid agent decontamination. These findings are supported by previous test results accomplished by ERDEC. Table 5 shows ratings assigned based on liquid phase testing.

Table 5. Live Agent Liquid Phase Test Results: Below are the ratings of GD-5's ability to decontaminate selected live agents.

	Time to Decon	Vendor Claim	NATO Standard
HD	>60 min	▼	▼
GD	<2 min	▲	▲
VX	<12 min	▲	▲

▲ – Demonstrated utility
▼ – Potential utility; not deployable now; significant improvements required

Aerosol Phase Test Results

Aerosol testing was accomplished as a two-step process. The first process step, which established qualitative data important to the overall aerosol evaluation, included using a man-portable Gas Chromatograph-Mass Spectrometer (GC-MS) system (Hapsite) to identify individual unidentified chromatographic peaks on CW material coupons. A Chemical Agent Monitor (CAM) and a Proengin AP2C (French CAM) were used, in addition to the Hapsite, to assess the GD-5 solution to determine if the decontaminant, by itself, posed any operational detection impacts. The qualitative data initially reported from the Hapsite in the September 2000 Quick Look Report indicated that GD-5 was effective in neutralizing HD, GD, and VX to the operational level. Further analysis of the Hapsite data substantiated results observed in later testing using the Varian GC in that a high mass ratio of GD-5 to CW agent was required to effect decontamination. The Hapsite findings, while qualitative, involved moving the sample coupons around by hand, resulting in solution mixing similar to that observed in later bulk application experiments. The Hapsite also heated the test sample for a few seconds to increase the vapor pressure and produce more vapor for analysis. Heating the samples and mixing the agents and decontaminant would have resulted in an increased chemical reaction rate. According to the DRES, it is a commonly held belief that an increase of 10^{o} C will result in an increased organic reaction rate.

The second and last laboratory test process step involved using several different aircraft material coupons and CW agents (HD, GD, and VX). Lessons learned from the use of the Hapsite were applied to tests conducted with the Varian GC (e.g., high mass ratio of GD-5 to CW agent). A Thin Layer Chromatograph sprayer was used to aerosolize the GD-5 in the appropriate mass ratio for agent decontamination onto material coupons where it coalesced as a continuous film of material over the CW agents. No mechanical or viscous mixing of the GD-5 and CW agents occurred on the coupon surfaces. Test results from this evaluation are significantly different from those reported by either LC-MS or Hapsite. For example, using bulk liquid application onto an aluminum coupon without additional mechanical mixing (other than pouring) indicates a decontamination half-life of approximately two hours. Repeating the same experiment using the aerosolized GD-5 yielded an apparent half-life of 18 hours. The aerosolized experiment was carried out for only 12 hours, the apparent half-life was estimated via extrapolation. The test cell used in the aerosolized experiment was opened after approximately 19 hours post decontamination and liquid HD was visually observed on the aluminum coupon. The HD was found adhering to the aluminum surface and was completely covered by GD-5 but had not mixed with it even after 19 hours exposure to liquid GD-5. At 24 hours post GD-5 application, liquid HD could still be seen. At 36 hours after GD-5 application, liquid HD was no longer visually observable. However, the use of a CAM produced a six-bar reading in H-mode for the opened test cell contents, indicating an unacceptably high concentration of HD above the decontamination mixture. An analysis of this finding indicates that GD-5 and liquid HD, when placed in contact, do not readily inter-mix without some sort of mechanical or viscous mixing. Since the CW agent and decontaminant have to be in intimate contact, or in solution with each other, for a decontamination reaction to occur, this would explain all the results observed, including those reported by ERDEC. (The results reported by ERDEC are indicative of a very well mixed reaction system.) When GD-5 is applied as an aerosol to decontaminate HD, there is no shearing or viscous forces generated to promote mixing of the fluids. As a result, the liquid HD remains as a continuous mass while airborne droplets of GD-5 coalesce into a layer that covers it. Test results indicate that the same liquid phase test ratio of GD-5 to HD blanketing the liquid agent is insufficient to prevent dangerous levels of HD vapor from escaping during aerosol applications. Table 6 depicts ratings based on aerosolized test results of GD-5 on HD. The overall effectiveness of aerosolized GD-5 on CW agents embedded in and on aircraft materials indicate that more mass ratio of decontaminant is needed for agent neutralization (see Appendix B for detailed results).

Table 6. HD Aerosol Test Results: Aerosolized testing did not prove to be successful.

	AMC Requirement	NATO Standard
HD	▼	▼

▼ – Potential utility; not deployable now; significant improvements required

Problems Incurred During Nerve Agent Testing

Initial GD testing using a decontaminant ratio of 58.8:1 in the Varian GC-MS resulted in a 100% reduction of GD in 30 minutes following spraying of GD-5. Subsequent nerve agent testing in the GC-MS did not have the same success. The GD-5, when applied as a cold or ambient decontaminant, does not completely dry, rather it remains a tacky viscous solution. As a result of the cold/ambient fogging of GD-5 into the diffusion cell and the viscous characteristics exhibited by the GD-5, the GC-MS was unable to quantitatively analyze degradation of either GD or VX. Essentially, the GD-5 became concentrated on the HayeSep D sample pre-concentration tubes used in the GC-MS to quantitatively collect nerve agents for degradation analysis. Through the use of a Pulsed Flame Photometric Detector on the Varian GC, the presence of phosphorous was determined, indicating degradation of GD. The same problem in conducting VX analysis was identified. The first step in the analysis of VX in a GC requires conversion of VX to the corresponding G agent analog o-ethyl methyl phosphino fluoridate by passing the sample stream through a conversion pad. This process produces a phosphorous ester fluorine identical to that seen in GD.

Due to the problems incurred with the Varian GC-MS, analyses of nerve agents GD and VX data were augmented by both Hapsite GC-MS and LC-MS to provide qualitative decontamination analysis. Overall findings indicate, as they did in the LC-MS analysis, that a high mass ratio of decontaminant is needed for agent neutralization (see Appendix B for detailed results). Aggregated LC-MS, Hapsite GC-MS, and Varian GC-MS data indicate that GD-5 is more effective on nerve than blister agents. Table 7 provides ratings assigned by aggregated liquid and aerosolized test results.

Table 7. GD and VX Aggregated (Aerosol and Liquid Phase) Test Results: Nerve agent decontamination was accomplished.

	AMC Requirement	NATO Standard
GD	△	▲
VX	△	▲

▲ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities

Corrosion and Sensitive Equipment Test and Results

The scope of the corrosion evaluation included two data assessment elements: corrosion testing of coupon materials typically found in cargo bays of military aircraft and a sensitive equipment functionality evaluation. To accomplish the corrosion test from an operational standpoint, GD-5 was applied as an aerosol, as it would be under operational conditions. Both OWR applicators (DECOFOG IV and TURBOFOGGER) were used to apply the GD-5 (see Figures 7 and 8). Corrosion testing was conducted on both metal and acrylic coupons and conformed to established American Society for Testing and Materials (ASTM) Standards G1-90, G46-94 and G31-72 (all three re-approved in 1999). Sensitive equipment testing was carried out by aerosolization, the same manner as the corrosion testing. While corrosion testing followed established ASTM guidelines, sensitive equipment testing was only conducted through functionality testing and was evaluated on a pass/fail basis.

Figure 7. DECOFOG IV Application: The DECOFOG IV was used only during the corrosion test (as shown here).

Figure 8. TURBOFOGGER Application: The TURBOFOGGER was used for the corrosion test (as shown here) and the field demonstration.

Corrosion results were obtained through microscopic examination and coupon weight loss. All signs of corrosion, such as discoloration, flaking of paint, cracking, and pitting, were recorded (see Figures 9 and 10). Microscopic examination of all the coupons after fogging by both applicators revealed very minor pitting on only the brass and copper coupons by the DECOFOG IV. The GD-5 did not dry to a powdery residue as identified by the manufacturer but remained as a tacky viscous residue. GD-5 had virtually no affect on the Aluminum 2024 T3 coupon (Figure 11).

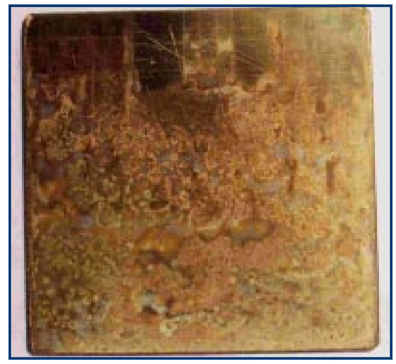

Figure 9. Brass Coupon: Coupons were washed in accordance with industry standards after fogging with GD-5.

Coupons were sprayed for 20 seconds at a distance of 2.5 feet from fogger. According to the OWR instruction manual, unit settings correlate to the following: 1 – gasification of the chemical solution; 2 – dry fog with a small droplet size; 3 – normal moist fog; 4 – wet spraying fog for special applications that require a considerable amount of chemical. Setting 5 was not used during corrosion testing as over-spray conditions resulted at Setting 4.

Figure 10. Copper Coupon: Coupons were washed in accordance with industry standards after fogging with GD-5.

Coupon weight loss was determined through the use of an analytical balance and reported to the nearest 0.1 milligram. Each coupon was weighed prior to having GD-5 fogged onto it to determine its initial weight. Each coupon was again weighed at regular intervals after being subjected to the GD-5 to determine coupon weight loss.

ASTM Standard G1-90 was used to determine the average corrosion rate of the coupons after being exposed to GD-5. Corrosion rates are expressed in mils per year (Table 8). According to the National Association of Corrosion Engineers (NACE) Standard TM 169-76, a benchmark of 2.0 mils per year is considered excellent.

Figure 11. Aluminum 2024 T3 Coupon: Coupons were washed in accordance with industry standards after fogging with GD-5.

Table 8. Average Corrosion Rate (mils/year): Corrosion rates are considered excellent by industry standards.

Average Corrosion Rate (mils/year)				
	Brass	Copper	2024 T3 Aluminum	7075 T6 Aluminum
Setting 1	1.53	0.91	0.18	0.03
Setting 2	1.59	1.68	0.07	0.07
Setting 3	1.61	1.64	0.08	0.04
Setting 4	1.50	1.14	0.04	0.05
DECOFOG IV	0.64	0.67	0.02	0.01

Corrosion Results

GD-5 did not prove to be corrosive to the metals tested. In fact, according to NACE standards, it was rated as excellent. The only anomaly noted was in acrylic. The GD-5 tended to drift on the surface of acrylic.

Sensitive Equipment Test

Operational testing on sensitive equipment was accomplished by fogging GD-5 onto equipment and taking measurements after the application over a three-week period to determine functional impacts to equipment (Figures 12 and 13). In addition to the sensitive equipment evaluation, a pressure test was also performed to determine impacts to gaskets protecting sensitive equipment.

The sensitive equipment items were electronically monitored and events time tagged to determine when an equipment item failed. The computer, which was externally fogged, drew aerosolized GD-5 into its electronics through the cooling fan from behind its central processing unit rather than opening the system and having its components fogged directly.

During the three-week sensitive equipment evaluation, the following results were observed. The computer continued to operate without failure; however, one non-conformal coated network card that was externally fogged did fail during the test. Otherwise, the electronic calculators and organizers continued to operate and function properly, as did the electronic cables and switches. Additionally, the casing with the gasket exposed to GD-5 continued to hold 40 psi over the three-week test. (It should be noted that the computer printer multi input/output card failed for undetermined reasons the day following the test.)

Figure 12. Spraying Board with Switches and Calculators Attached: Switches and calculators were chosen as representative of sensitive equipment on LFA.

Figure 13. Computer and Printer Setup: The computer was chosen as representative of sensitive equipment on LFA.

Phase I Findings and Recommendations

Laboratory live agent testing conducted on GD-5 indicates that, under controlled conditions where the decontaminant and CW agents are mechanically or viscously mixed, it could neutralize CW agents within the NATO standard of 30 minutes. However, GD-5 did not continue to perform within NATO standards on all CW agents tested when applied as an aerosol as proposed by this FCT. GD-5 proved to be more effective against nerve than blister agents tested. The GD-5 did not prove to be corrosive and in fact was rated as excellent with respect to corrosion impacts on a mils/per year standard. Neither did GD-5 negatively impact sensitive equipment. It did not, however, dry to a powdery residue as identified by the manufacturer.

It should be noted that live agent testing was only evaluated using a cold fogging application for safety reasons and was sited earlier as a test limitation due to a fire combustion test accomplished at Tyndall AFB Air Force Research Laboratory (AFRL) facilities. The Tyndall study did not, however, evaluate the GD-5 and its associated applicators in a complex aerosol environment, as it would be subjected to in concurrent aircraft operations. As a result of this limitation, the GD-5 was not thermally tested during this FCT against CW agents, which, as previously sited by DRES, could result in an increased decomposition reaction of CW agents.

It is recommended that follow-on testing be conducted to fully characterize the DECOFOG IV and GD-5 in a complex aerosol environment to fully determine the safety issues it presents to aircraft operations. In addition, it is recommended that thermal testing of GD-5 be conducted to determine if the temperature elevation of GD-5 will hasten the degradation of CW agents.

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SECTION 3
MILITARY UTILITY ASSESSMENT
PHASE II TEST OVERVIEW AND RESULTS

OVERVIEW

Det 1 conducted the MUA field demonstration at Davis-Monthan AFB using a C-141 aircraft prior to its decommissioning (Figure 6). The C-141 was selected, due to its availability, as representative of Air Force LFA. Supporting laboratory and program office personnel augmented Det 1 test personnel for technical assistance and continuity purposes during the GD-5 interior aircraft demonstration. The primary objective of the MUA was to assess whether this FCT answered AMC's requirement for timely operational decontamination of aircraft operating in a chemical environment.

Task 3: Application of GD-5 using fogging techniques supports sortie generation and rapid aircraft turnaround in a chemical warfare environment.

While live CW agent testing is prohibited at Davis-Monthan AFB, a CW agent simulant, MES, was used to facilitate the demonstration and stress the chemical agent detectors used during the field test. The basis for determining military utility of the FCT was based on answering the following operational requirements:

- Decontaminate an unloaded or loaded cargo compartment within one hour
- Operate continuously for one hour without resupply
- Fit in the crew entrance door
- Be man-portable with a maximum weight of 100 pounds
- Be ready to use without decontaminant processing or testing
- Use an easily refilled/recharged, non-hazardous applicator

Three MUA field test scenarios and aircraft configurations were developed to answer the operational requirements of the FCT. Each scenario, or trial run, was designed to begin with the detection of a chemical agent. The scenarios were built around three different aircraft configurations. These configurations simulated normal airlift operations.

Timely operational CW agent decontamination of an aircraft is determined to have been accomplished when "all" actions required for decontamination have been completed within one hour. For example, to operationally decontaminate an aircraft and certify it ready for reuse CW agent decontamination must be completed within the NATO standard of 30 minutes. HQ AMC would like to further reduce the time to decontaminate to 15 minutes to expedite aircraft turnaround. By combining the laboratory time to decontaminate CW agents with the operational response requirements for field applications, such as time to don protective gear, transit to the aircraft, preparation of the applicator for use, and fogging of the cargo compartment, one can determine if all actions can be accomplished within the one-hour standard.

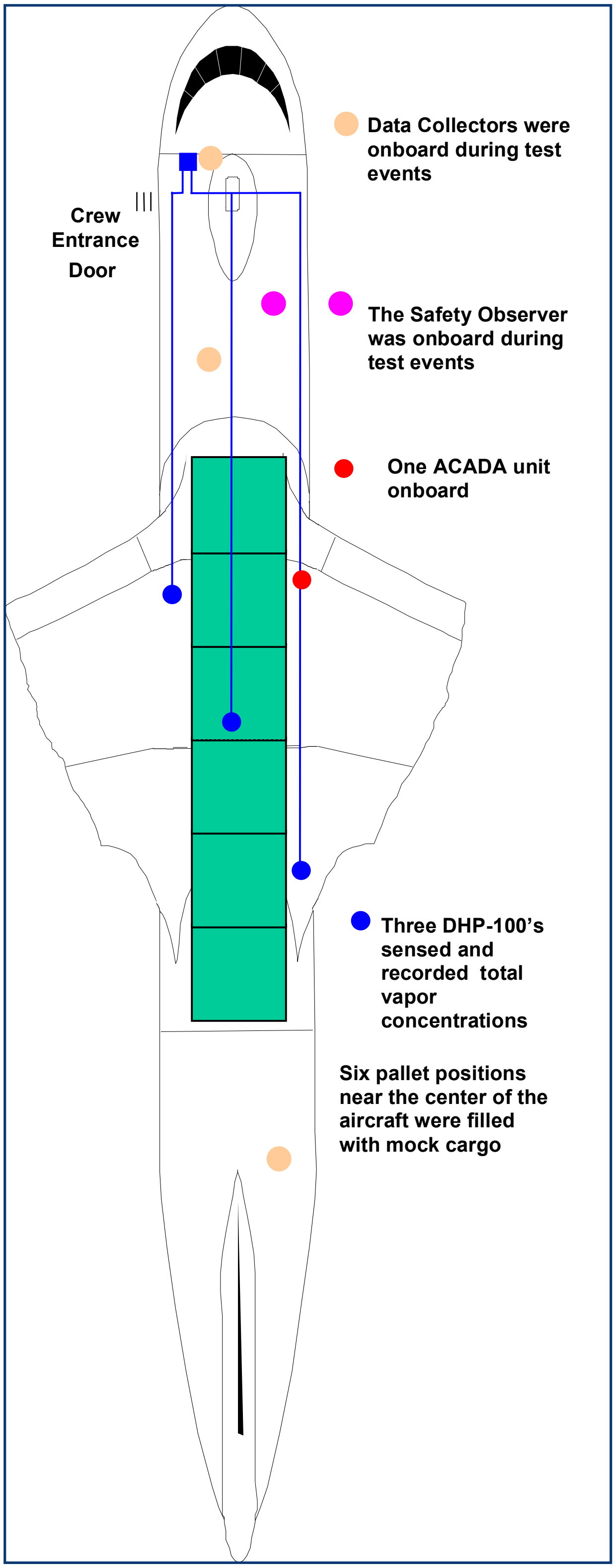

Figure 14. C-141 Compartment Diagram: A safety observer, data collectors, and instrumentation were positioned on the C-141 during test events.

- aircraft doors and cargo ramp open with aircraft air conditioning system off, as during preflight operations such as loading and unloading
- aircraft doors and cargo ramp closed with aircraft air conditioning system on but not pressurizing, to emulate taxi operations (this was conducted with an auxiliary charge cart)
- aircraft doors and cargo ramp closed with aircraft air conditioning system on and aircraft pressurized, emulating in-flight operations (aircraft engines up to 80 percent power and aircraft pressurized to sea level to simulate in-flight altitudes up to and including 18,000 feet)

The C-141 was instrumented at all times during the aircraft decontamination exercises to remotely evaluate the potential for chemical off-gassing and determine aircraft interior vapor levels. Three different instrumentation systems (two chemical agent detectors and three hydrocarbon sensors) were used during the MUA. The two chemical agent detectors used were the Automatic Chemical Agent Detector Alarm (ACADA) and the CAM. The third instrumentation set used was Fiber Optic Digital Hydrocarbon Probe (DHP) 100 or DHP-100. These probes detect the presence of hydrocarbon vapors and total vapor concentrations. The ACADA was used to initiate the beginning of the test signaling the detection of a CW agent. The CAM was used to determine GD-5 neutralization of MES. The DHP-100 was used to establish total vapor concentrations inside the aircraft prior to each test run. The DHP-100s also quantitatively reported the amount of vapor concentrations produced by the TURBOFOGGER and GD-5 during each test event, to establish a correlation between the total parts per million (ppm) and mg/m^3 concentrations needed to effect decontamination of CW agents. See Figure 14 for aircraft configuration. Instrumentation results were augmented by questionnaires administered to decontamination personnel following each test event.

Six decontamination teams, consisting of both Air Force and Marine Corps personnel who have the primary responsibility of aircraft decontamination, participated in the MUA. Decontamination teams were set up as two-person teams to accomplish the mission of decontaminating the C-141. Due to the close proximity of the decontamination response teams to the aircraft, times to respond were approximated. Timed events began for each scenario with the decontamination teams dressed in MOPP IV ready to perform CW agent decontamination. Prior to the start of each scenario, a total vapor background reading was obtained from the DHP-100 sensors. Once vapor backgrounds were established, the ACADA was triggered and the decontamination teams began preparing the TURBOFOGGER by filling it with GD-5 and laying out the power cord to run the applicator. TURBOFOGGER switch settings of 2-4 were used and recorded for each trial run during the MUA.

MUA RESULTS

The basis of each scenario was that a CW agent was released inside the cargo bay of the C-141. Isolation of the point of agent release was not required. The primary objective of each scenario was how well the TURBOFOGGER performed its mission of dispensing the GD-5 to a level that could affect agent decontamination inside the C-141 cargo bay.

Each decontamination team performed fogging applications at different speeds consistent with their experience levels, training, and exposure to the TURBOFOGGER. Use of the TURBOFOGGER around the mock cargo did not prove to be difficult. The ability to visually see the dispensed solution as a fog helped the teams determine the speed at which they performed their tasks for each scenario. The average time to fog the C-141 cargo bay during the MUA was six minutes. The average dispensed GD-5 concentration in ppm values during the MUA for TURBOFOGGER settings 2, 3, and 4 are presented in Figure 15. For a detailed analysis of concentrations for each scenario, see Appendix D.

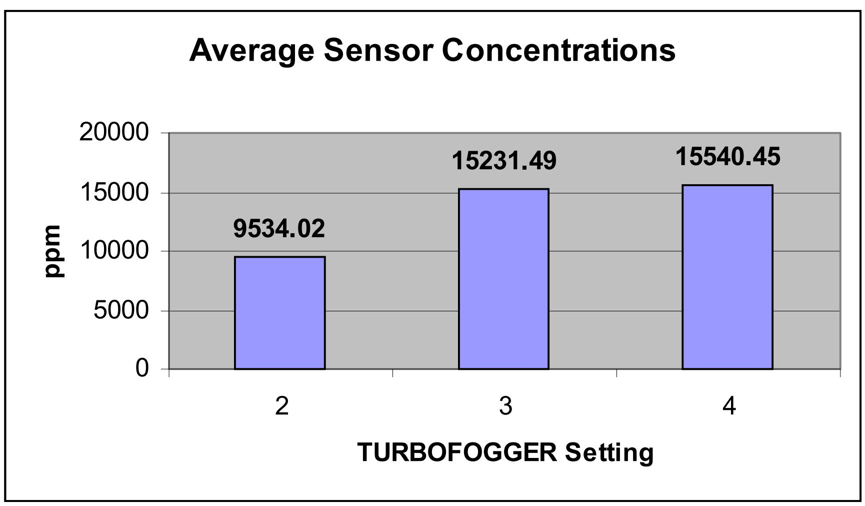

Figure 15. Average Sensor Concentration Readings from the DHP-100s: Readings were taken during each decontamination event.

The total time to decontaminate the C-141 is based on an average estimated time to respond to the event of 30 minutes plus system preparation and decontaminant dispensing. Obviously, it will take longer to respond to a ground operation than it will for an in-flight operation based on proximity of response personnel. As a result, the ability of the TURBOFOGGER and GD-5 to meet the one-hour time frame for cargo compartment decontamination is directly affected by where the response personnel are located. In the case of in-flight operations the time to respond is less. Therefore, it is entirely possible, based on the speed with which the GD-5 neutralizes CW agents, that CW agent decontamination may be accomplished for in-flight operations but not accomplished in a timely manner for ground operations (Figure 16).

Figure 16. Interior Decontamination: Crews fogged the C-141 using the GD-5 solution and the TURBOFOGGER applicator.

Lastly, due to the way the MUA was constructed, there was no attempt to determine effects of aerosolized GD-5 on concurrent aircraft operations, such as aircraft fueling and liquid oxygen servicing. Further testing would be required to determine complex aerosol impacts exhibited by using GD-5 during concurrent activities.

Phase II Findings and Recommendations

"It (the TURBOFOGGER) would definitely be usable in a quick turn situation on an airplane, it is fully applicable there."

-Aircraft Maintainer-HQAMC/LG

Overall the MUA field demonstration proved to be extremely successful. Supporting personnel who actually performed aircraft decontamination felt that they could use the applicator to perform their assigned tasks.

Fogging applications indicated that the fog moved from nose to tail throughout the cargo bay and out the weep valves in the aft end of the aircraft when pressurized. As a result of this air movement through the cargo bay, the need to maintain sufficiently high concentrations of aerosolized GD-5 is critical to CW agent decontamination.

The TURBOFOGGER proved to be easy to use and maneuver, and its weight when full still made it fully transportable by one person. Since no pre-mixing or mixing of GD-5 is required, preparation of the system was accomplished by simply pouring GD-5 into the system solution tank. (All actions involving the TURBOFOGGER were accomplished while in MOPP IV.)

It is recommended that complex aerosolization testing be accomplished to determine the effectiveness and impacts of GD-5 on concurrent flight operations and servicing. The capabilities of the DHP-100 should be researched in relationship to CW agent detection, as it is a commercial off-the-shelf (COTS) system that can be readily adapted to CW agent detection.

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SECTION 4
TEST AGGREGATION RESULTS

This section explains how Det 1 met the objective of this FCT qualification test/MUA in demonstrating a foreign, commercially available system's capability to remove selected chemical agents from representative aircraft and cargo materials. Removal of such agents would allow decontamination of airlift assets to the operational level and thus support USAF strategy to maintain contingency operations delivery flows in a chemical warfare environment.

The two phases of the test/utility assessment together addressed three main tasks, which must be accomplished by GD-5 chemical decontamination if this system is to be a viable option for improving AMC's airlift operations in a chemical environment. The FCT assessment measured GD-5 and the TURBOFOGGER applicator's performance against criteria based on vendor claims, AMC requirements and selected requirements from the JSSED ORD. Data were collected to evaluate these requirements during both phases of testing. The mechanism Det 1 used to link these test requirements to task accomplishment is how well an MOE meets or does not meet a task objective. By linking MOEs to the applicable task, Det 1 was able to determine how well the GD-5 and TURBOFOGGER met AMC requirements for the FCT. A summary of task level results is provided in Table 9.

SYSTEM PERFORMANCE

Task 1: Application of GD-5 using fogging techniques neutralizes chemical warfare agents to the operational level.

Task 1 was developed to answer sponsor concerns regarding the efficiency of neutralizing chemical warfare agents. Successful decontamination of chemical agents is fundamental to the deployment of any decontamination system by AMC for operational use.

Data used to evaluate GD-5 under this task were collected predominantly during the materials live agent decontamination test (Phase I). Agents HD, GD, and VX were used to gather data on agent neutralization. Observations relative to neutralization of chemical simulants were collected in both the materials live agent decontamination test and the field demonstration (Phase II).

Data collected by the materials live agent decontamination test shows that the GD-5 is effective in laboratory liquid phase testing. Aerosolized decontamination of CW agents was not as effective as in liquid phase testing.

Table 9. Test Summation and System Performance Summary: MOE results were aggregated to determine the overall utility rating for each task.

TASK	DESCRIPTION	UTILITY	REMARKS
1	Application of GD-5 using fogging techniques neutralizes chemical warfare agents to the operational level.	Does not provide utility beyond current capabilities.	Cold/Ambient aerosolized GD-5 did not prove to be more effective than currently fielded decontaminants • GD-5 is not effective in neutralizing HD to the operational level in timelines required by AMC and NATO standards • GD-5 is not effective in neutralizing HD to below the immediately dangerous to life and health (IDLH) level in timelines required by AMC and NATO standards
2	Application of GD-5 using fogging techniques decontaminates LFA interiors without corroding sensitive equipment or creating hazards.	GD-5 has military utility though modifications are recommended	GD-5 satisfies operational requirements in the following areas: • No deleterious effects on sensitive equipment from GD-5 exposure were noted in 97% of the test cases • Minimal corrosive effects on material from GD-5 exposure
3	Application of GD-5 using fogging techniques supports sortie generation and rapid aircraft turnaround in a chemical warfare environment.	The TURBOFOGGER has utility for military applications though modifications and follow-on testing are recommended.	GD-5 satisfies operational requirements in the following areas: • Decontamination using GD-5 fog is feasible during ground operations • Decontamination using GD-5 fog is feasible during flight operations • Representative users found GD-5 fogging using the TURBOFOGGER to be effective

MOE 1.1: Effectiveness of GD-5 in decontaminating the chemical agents (or simulants).

This MOE was designed to determine how well GD-5 fulfilled chemical warfare agent decontamination to the operational level.

Results: Results from the materials live agent decontamination test indicate that GD-5 was effective in neutralizing HD, GD, and VX to below operational levels in laboratory liquid phase testing.

However, GD-5 did not prove to be effective against HD in an aerosolized application. Aerosol decontamination exceeds both NATO and AMC standards for timeliness of HD agent decontamination. GD-5 was effective in neutralizing GD, VX, and the simulants DEM and MES. Neutralization of MES by GD-5 was confirmed by using both M-8 and M-9 detection paper as part of the field demonstration.

MOE 1.2: Effectiveness of GD-5 in decontaminating the chemical agents to below toxic [immediately dangerous to life and health (IDLH)] levels.

This MOE differs from the previous one in that it was developed to evaluate the levels of residual toxic materials following decontamination. Assessment of neutralization to below IDLH levels relates to toxic level exposure of personnel following decontamination.

Results: The results from the materials live agent decontamination test (liquid phase) are that GD-5 was effective in decontaminating HD, GD, and VX to below toxic levels within 30 minutes. The time to completely neutralize HD, GD, and VX to below IDLH values through aerosolization of GD-5 was in excess of 30 minutes.

Task 2: Application of GD-5 using fogging techniques decontaminates LFA interiors without corroding sensitive equipment or creating hazards.

Decontamination of LFA without corrosion or hazard is the second issue deemed critical in this FCT. Det 1 based its assessment of GD-5's military utility for accomplishing decontamination without corrosion or hazard on data collected during both the GD-5 corrosion test and the field demonstration. The corrosive effects documented during this FCT were those of GD-5 only and do not reflect effects of the decontaminant after it has been applied to a live chemical agent.

GD-5's vendor claims that the solution is non-aqueous, non-corrosive, produces no harmful residue, and is environmentally safe. The JSSED ORD calls for any decontaminant used to be non-aqueous, non-corrosive, nontoxic, disposable, biodegradable, and less hazardous than current decontaminants.

Data collected during GD-5 corrosion test did not indicate adverse effects to either sensitive equipment or materials.

MOE 2.1: Percentage of time that GD-5 does not impact sensitive equipment.

Det 1 used this MOE to assess the effects of GD-5 on equipment found aboard LFA. During the GD-5 corrosion test, the following items were chosen to be representative of sensitive equipment found on LFA for the assessment of this MOE (and MOE 2.3):

- calculator (4)
- personal computer (1)
- circuit cards [2 non-conformal coated, 2 conformal coated with silicon (50:50 mix of acrylic resin to polymethylphenylsiloxanes)]
- stainless steel casing with gasket (1)
- single pole electrical switches (5)
- electrical cable (6, 14, 22 gauge – 1 each intact, 1 each nicked)

The effects of GD-5 on these systems were recorded at predetermined intervals over a three-week period.

Det 1 also observed impacts on the C-141 used during the field demonstration to evaluate the military utility of the GD-5 decontaminant.

Results: Overall results indicated that GD-5 had minimal impact on sensitive equipment that was tested. While the computer continued to operate without failure during the three-week evaluation, one non-conformal coated network card did fail during the test.

MOE 2.2: Percentage of time that GD-5 does not corrode aircraft materials.

Det 1 used this MOE to assess the short-term and accelerated growth effects of GD-5 on selected LFA materials.

The following items were chosen during the corrosion evaluation to be representative of materials found in and on LFA for the assessment of this MOE (and MOE 2.4):

- Brass
- Copper
- Acrylic
- 2024 T3 aluminum
- 2024 T3 anodized aluminum
- 2024 T3 alodined aluminum
- 2024 T3 alodined, primed, and painted aluminum
- 7075 T6 aluminum
- 7075 T6 alodined aluminum
- 7075 T6 alodined, primed aluminum

Corrosion testing was accomplished using ASTM Standards G1-90, G46-94, and G31-72. Test results were determined using both microscopic and visual inspections on material coupons and by measuring coupon weight loss to assess corrosive effects of GD-5 exposure.

Results: Visual inspection revealed discoloration of unprotected metal and at least partial removal of alodine coatings. Analysis of weight changes for each of the metals showed very little corrosion resulting from GD-5. The minimal weight loss of coupon material following application of GD-5 indicated that the decontaminant was not excessively corrosive. According to the NACE Standard TM 169-76, the corrosiveness of GD-5 was rated as excellent, as it only displayed an average corrosion rate of less than two mils per year on metals that were tested. Similar analyses on the acrylic samples were inconclusive.

MOE 2.3: Percentage of time that GD-5 remains on sensitive equipment for 180 minutes.

Using Pacific Air Forces CONOPS, Det 1 developed the standard of 180 minutes resident time to determine effectiveness of GD-5 relative to natural attenuation of nerve agents. According to Pacific Air Forces, VX volatilizes to below miosis (or operational) levels through natural processes in approximately 180 minutes. It was determined that if GD-5 remained viable on surfaces in a sufficient decontaminant to agent ratio, GD-5 would neutralize all agents that naturally drop to below miosis levels faster than if no decontaminant were applied.

Results: Analytical weight balance measurements were taken during the GD-5 corrosion test to determine the presence of GD-5 on the surface of sensitive equipment tested. On average, 99% of sprayed GD-5 stayed resident on materials coupons over a three-hour period.

MOE 2.4: Percentage of time that GD-5 remains on aircraft materials for 180 minutes.

Refer to MOE 2.3 for an explanation of the significance of this measure.

Results: The resident amounts of GD-5 on coupon samples were determined using the weight loss techniques employed during the GD-5 corrosion test. Over a three-hour period, 99% of sprayed GD-5 remained resident on materials coupons.

MOE 2.5: Characteristics of GD-5 decontaminant solution.

GD-5 characteristics, under this MOE, relate to the task of decontamination without corrosion, and safety or environmental hazards based on the constituents of GD-5. GD-5 Occupational Safety and Health Administration (OSHA) MSDSs were examined to determine the characteristics of the GD-5 based on its components. The toxicity of GD-5 and its by-products when applied to chemical agents were analyzed in the materials live agent decontamination test.

Results: It was determined, through MSDS information, that GD-5 is non-aqueous and is less hazardous than most currently fielded decontaminants. Shipping, storage, handling, and disposal of GD-5 should be conducted in accordance with local, state, and federal regulations, as it is both a hazardous material and, when used, a hazardous waste.

Task 3: Application of GD-5 using fogging techniques supports sortie generation and rapid aircraft turnaround in a chemical warfare environment.

Assessment of GD-5's military utility for supporting sortie generation, aircraft turnaround, and, ultimately, operational tempo and the CINC's delivery flow was based on data collected primarily during the FCT's MUA field demonstration. Human factors data were collected during all phases of the FCT.

Test data on the DECOFOG IV applicator were only collected during the GD-5 corrosion test. The DECOFOG IV applicator heats GD-5 to over 1100^0 F before dispensing it as a fog. During the corrosion test, flame was occasionally observed at the tip of the applicator barrel while attempting to dispense GD-5. Based on these observations and the AFRL combustion test, both AMC and 311 HSW/YACN approved the Det 1 recommendation not to use the DECOFOG IV during the MUA. More data on the DECOFOG IV unit are required to determine its applicability in complex aerosol environments. While no data were collected on the DECOFOG IV during the MUA, data were collected on the TURBOFOGGER during both the GD-5 corrosion test and the MUA.

GD-5 vendor claims tout the ease with which the applicators are prepared and used. The JSSED ORD calls for decontamination to be done for all aircraft interior surfaces, both on the ground and in-flight, rapidly and in varied climatic and operational environments. The utility of GD-5 was assessed using these and other criteria.

MOE 3.1: Percentage of trials where GD-5 fogging decontaminates chemical simulant in LFA interiors and cargoes supporting mission requirements for ground operations.

Results gathered for this MOE were used to assess potential operational concepts for using GD-5 applicators during normal airlift ground operations. Test personnel gathered data to assess GD-5 utility during ground operations as part of the MUA's dedicated field demonstration. This demonstration was conducted onboard a C-141 with a mock cargo load. Only the TURBOFOGGER applicator was used during the field demonstration for reasons previously cited.

Results: Decontamination crews successfully fogged the C-141 interior with GD-5 in all trial runs/events conducted. Figure 17 indicates the volume of GD-5 dispensed during ground operations as measured by the DHP-100s.

MOE 3.2: Percentage of trials where GD-5 fogging decontaminates LFA interiors and cargoes supporting mission requirements in a flight mode.

Potential operational concepts were addressed using the GD-5 and TURBOFOGGER during normal airlift flight operations under this MOE. The aircraft's flight mode was simulated by closing all aircraft doors, running aircraft engines (to generate adequate bleed air volume), and pressurizing the aircraft interior. Differential pressures of up to 1.1 pounds per square inch were achieved during the field test. This differential pressure maintained aircraft altitude at sea level while the aircraft was at 2500 feet above mean sea level. As a point of reference, the C-141 is capable of maintaining its cabin at sea level pressure up to a flight altitude of 18,000 feet above mean sea level.

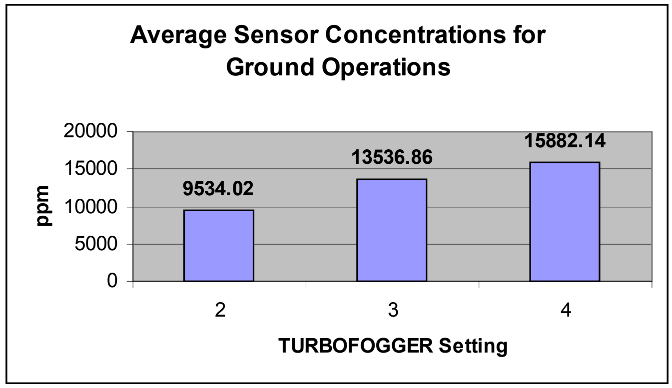

Figure 17. Average Sensor Concentrations for Ground Operations: Readings were taken during each decontamination event.

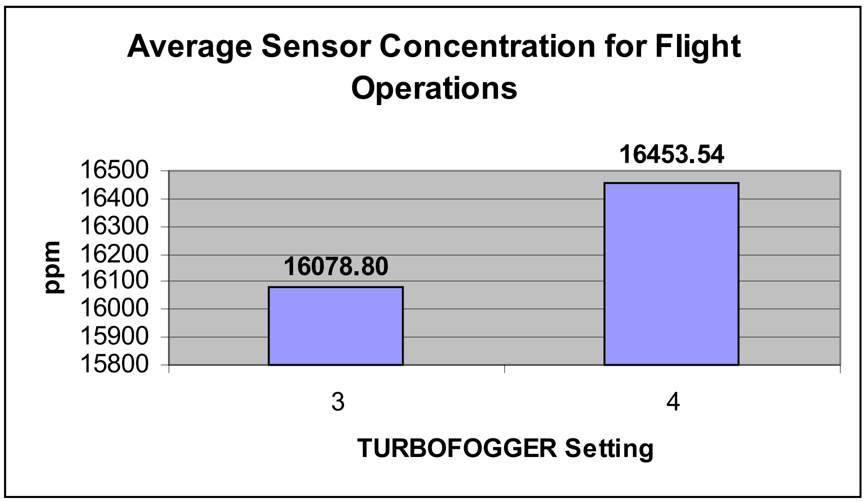

Figure 18. Average Sensor Concentrations for Flight Operations: Readings were taken during each decontamination event.

Results: As with MOE 3.1, decontamination crews successfully fogged the C-141 interior with GD-5 in all trial runs/events conducted. Figure 18 indicates the volume of GD-5 dispensed during in-flight operations as measured by the DHP-100s.

MOE 3.3: Representative user ratings of the applicator's capabilities to accomplish decontamination.

This MOE was developed to acquire user impressions and opinions of the TURBOFOGGER and GD-5 during operational use. User opinions provided critical data relevant to operational utility.

Results: The users of the DECOFOG IV applicator were the corrosion test personnel. User opinion of the DECOFOG IV applicator capabilities indicate that, although the applicator is easy to use, the excessive heat generated by the applicator could present a safety hazard if not fully characterized. The consensus opinion of

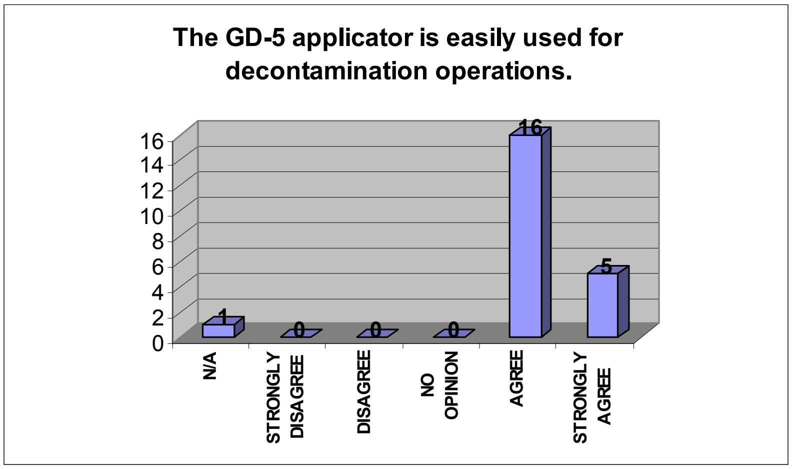

Figure 19. Field Demonstration Users' Opinion for Ease of Use of the TURBOFOGGER: Users felt the TURBOFOGGER applicator was easy to use.

TURBOFOGGER users (decontamination personnel from Air Force and Marine Corps) is that the system has utility to accomplish LFA decontamination. While users felt the TURBOFOGGER was easy to use and can, as is, support mission requirements (Figure 19), they also felt that the system needed a fog tap switch upgrade. The overall opinion on the fog tap switch was that it was difficult to maintain on one setting and needed a detent setting to keep the switch from moving while applying the decontaminant. In addition to the fog tap switch upgrade, the majority of users also felt that an upgrade of the solution tank cap was needed, because the tank cap removal and replacement was not always easily accomplished while in MOPP IV.

MOE 3.4: Representative user ratings of the applicator's dependability (or tendency to experience mission-impacting failures).

This MOE was developed to gather user opinion of the GD-5 and TURBOFOGGER during operational use. Results were obtained by questionnaires administered during the field demonstration and interviews conducted with decontamination system users.

Results: Of the eleven test events accomplished during the field demonstration using the TURBOFOGGER, the system malfunctioned once. The exact cause of the malfunction is unknown; however, the users felt that the most likely causes were improper sealing of the solution tank cap or a fog tap switch setting error. The malfunction only occurred with one decontamination team and did not present itself again. Since the malfunction happened on the team's first test run and did not occur again, the possibility of human error cannot be ruled out as a contributing factor in the systems malfunction. Overall the users felt that the TURBOFOGGER has utility for applying decontaminant and could be deployed now.

MOE 3.5: Representative user ratings of the GD-5 decontamination system's sustainability.

This MOE was developed to gather user opinion of the GD-5 and TURBOFOGGER during operational use. Results were obtained by questionnaires administered during the field demonstration and interviews conducted with decontamination system users.

Results: During the field demonstration, users felt that the TURBOFOGGER was easily used and transported by a single operator. While it was difficult for a left-handed operator to use the applicator, decontamination was still accomplished. The TURBOFOGGER that was tested required an external power adapter in order to operate on aircraft supplied power. Without adapting the system for use on aircraft, the capability of the system is diminished. The placement of the TURBOFOGGER's power cord does represent a concern, as sited by users, due to its rear placement on the system. The rear placement of the power cord could present a sustainability issue, as it could exhibit accelerated failures compared to repositioning it to the front of the unit. The GD-5 solution was considered sustainable in that it only requires storage and no mixing of chemicals to be ready for application. Aircraft storage of both the GD-5 and TURBOFOGGER are required, and since the solution is considered a hazardous material, appropriate precautions are needed.

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SECTION 5
LAID-FCT SUMMARY AND RECOMMENDATIONS

Summary

The scope of the LAID-FCT was to demonstrate the potential viability of a new concept of operations using a foreign NDI technology. To address the technology's potential value to DoD applications, the LAID-FCT was evaluated in two phases. The first evaluation phase demonstrated the GD-5's capability to decontaminate three chemical warfare agents (HD, GD, and VX). In addition to the decontamination of the chemical warfare agents, the GD-5 and associated applicators were evaluated to determine effects to sensitive equipment and corrosion of aircraft materials. In phase two of the LAID-FCT, a partially decommissioned C-141 cargo plane was used to collect user opinion on the effectiveness of the TURBOFOGGER applicator, the GD-5 solution, and their ability to expeditiously support decontamination of military cargo both on the ground and in-flight.

Phase I Findings and Recommendations

Laboratory live agent testing conducted on GD-5 indicates that under controlled conditions where the decontaminant and CW agents are mechanically or viscously mixed, GD-5 can neutralize nerve agents within the NATO standard of 30 minutes. However, GD-5 did not, in all cases, continue to perform within NATO standards on all CW agents tested when applied as an aerosol as proposed by the FCT. GD-5 proved to be more effective against nerve than blister agents. The GD-5 did not prove to be corrosive and in fact was rated as excellent with respect to corrosion impacts on a mils per year standard. Neither did GD-5 negatively impact sensitive equipment; it did not, however, dry to a powdery residue as identified by the manufacturer.

It should be noted that live agent testing was only evaluated using a cold fogging application for safety reasons and was sited earlier as a test limitation due to a fire combustion test accomplished at Tyndall AFB AFRL facilities. The Tyndall study did not, however, evaluate the GD-5 and its associated applicators in a complex aerosol environment, as it would be subjected to in aircraft operations. As a result of this limitation, the GD-5 was not thermally tested during this FCT against CW agents, which, as previously sited by DRES, could result in an increased decomposition reaction of CW agents.

It is recommended that follow-on testing be conducted to fully characterize the DECOFOG IV and GD-5 in a complex aerosol environment to fully determine the safety issues it presents to aircraft operations. In addition, it is also recommended that thermal testing of GD-5 be conducted to determine if the temperature elevation of GD-5 will hasten the degradation of CW agents.

Phase II Findings and Recommendations

Overall, the MUA field demonstration proved to be extremely successful. Supporting personnel who actually performed aircraft decontamination felt that they could use the applicator to perform their assigned tasks. The TURBOFOGGER either met or exceeded expectations for an applicator as identified in the JSSED ORD. Fogging applications indicated that the fog, when applied, moved from nose to tail throughout the cargo bay and out the weep valves in the aft end of the aircraft when pressurized. As a result of this air movement through the cargo bay, the need to maintain sufficient aerosolized GD-5 is critical to CW agent decontamination. (As sited in Section 2 of this report, the key to CW agent decontamination is the ratio of decontaminant to CW agent.)

The TURBOFOGGER proved to be easy to use and maneuver, and its weight, even when full, made it fully transportable by one person. Since no pre-mixing or mixing of GD-5 is required, preparation of the system was accomplished by simply pouring GD-5 into the system solution tank. (All actions involving the TURBOFOGGER were accomplished while in MOPP IV.)

It is recommended that further testing (complex aerosolization) be accomplished to determine the effectiveness and impacts of GD-5 on concurrent flight operations and servicing. The capabilities of the DHP-100 should be researched in relationship to CW agent detection, as it is a COTS system that can be readily adapted to CW agent detection.

Equipment Recommendations

The TURBOFOGGER applicator should be modified as follows to increase its military utility:

- The power supply should be self-contained. If such a modification is not feasible, then the equipment must be modified to operate on power most commonly available in LFA (such as 110 volt, 60 cycle, single phase).
- The solution tank cap should be modified to preclude difficulties in securing it while in MOPP gear.
- The fog tap switch used to set droplet size for fog generation should be modified to correct problems noted during the MUA field demonstration. The fog tap switch is difficult to see and can easily be moved from desired setting.

The following should be developed for the GD-5 decontamination system (including applicators) use by American forces:

- CONOPS
- Equipment storage and security provisions
- Maintenance concept
- Training concept

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SECTION 6
FOLLOW-ON TEST RECOMMENDATIONS

GD-5 was proposed as an FCT using the DECOFOG IV applicator because of the applicator's ability to thermally decontaminate chemical warfare agents. Due to AFRL's limited combustion testing of GD-5, the DECOFOG IV was not used in laboratory or field evaluations. Chemical warfare laboratories in the U.S., Canada, and England note that thermal application of decontaminants expedites chemical agent neutralization. As a result, the timeliness of the GD-5 to decontaminate chemical warfare agents should be re-evaluated as a thermal decontamination application. From a safety standpoint, the DECOFOG IV and GD-5 solution needs to be evaluated in a complex aerosol environment to determine effects to concurrent flight operations.

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APPENDIX A
UNITED STATES TRANSPORTATION COMMAND FCT CONSIDERATION REQUEST

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UNITED STATES TRANSPORTATION COMMAND
[illegible] SCOTT DR
SCOTT AIR FORCE BASE IL [illegible]

1 April 1999

MEMORANDUM FOR Dr. Patricia A. Sanders
Director, Test Systems Engineering & Evaluation
Office of the Under Secretary of Defense (A&T)
The Pentagon, Room 3E1060
Washington DC 20330

FROM: TCCC

SUBJECT: Foreign Comparative Testing (FCT) for Large Aircraft Interior Decontamination

1. The Chairman of the Joint Service Material Group (JSMG) has placed a high priority on this FCT in support of the nation's Chemical and Biological Defense Program. We, as the primary user, are also a strong advocate for testing the Decofogger and GD5 decontaminant. If manufacturer's claims are correct, this technology would advance our decontamination capabilities and address deficiencies identified by the Deterrence/Counterproliferation Joint Warfighting Capabilities Assessment CINCs' Counterproliferation (CP) Required Capabilities study.

2. Formal testing by countries throughout Europe has been successful for this system's intended application. It is crucial that this testing be completed to evaluate its applicability for interior large aircraft use. If GD5 is found to be a safe and effective method of decontamination for the interior of large aircraft, it may prove useful for cleaning other large areas (warehouses, aircraft exteriors, and cargo bays on ships, etc.). If successful, we would work with Joint Staff and Services to ensure procurement and adjustment of decontamination procedures.

3. Request favorable consideration of the testing proposal. Our USTRANSCOM point of contact is Mr. Bill Heisel or Major Doug Tauscher, TCJ5-SR, DSN: 576-6840, commercial: (618) 256-6840.

CHARLES T. ROBERTSON, JR.
General, USAF
Commander in Chief

cc: Chairman, Joint Service Materiel Group

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APPENDIX B
LIVE AGENT TEST RESULTS

Table B-1 depicts the overall ratings assigned to each MOE relating to the live agent testing portion of the FCT.

Table B-1. Live Agent Testing MOE Ratings.

MOE 1.1	△	Effectiveness of GD-5 in decontaminating the chemical agents (or simulants).
MOE 1.2	▽	Effectiveness of GD-5 in decontaminating the chemical agents to below toxic [immediately dangerous to life and health (IDLH)] levels.
MOE 2.4	▲	Percentage of time that GD-5 remains on aircraft materials for 180 minutes.
MOE 2.5	△	Characteristics of GD-5 decontaminant solution.

▲ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities
▽ – Potential utility; not deployable now; significant improvements required

These results, along with the results from the other portions of the FCT, were then aggregated to establish the overall rating for each task.

As is evident in Figures B-1 through B-4, aerosolized decontamination occurs more quickly with a higher GD-5 to agent ratio on the materials selected as representative of materials found on LFA.

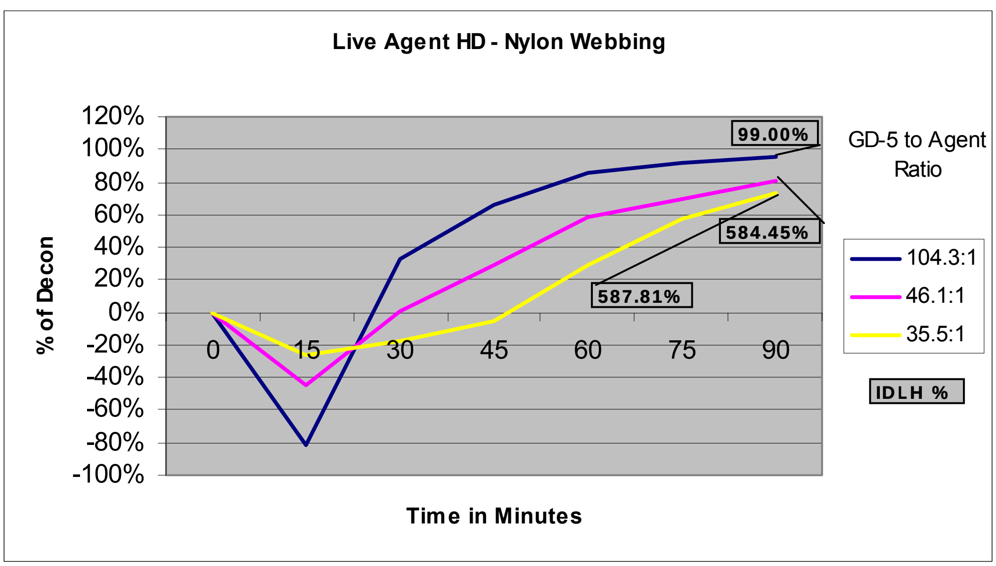

Figure B-1. Aerosolized GD-5 Decontamination Effectiveness Against HD on Nylon Webbing.

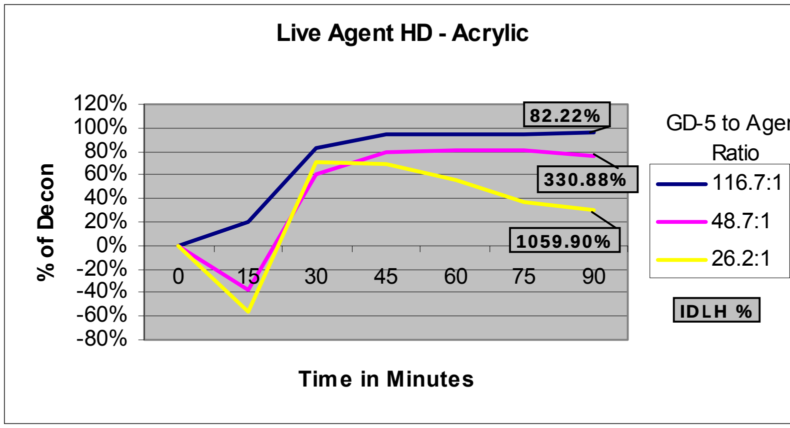

Figure B-2. Aerosolized GD-5 Decontamination Effectiveness Against HD on Acrylic.

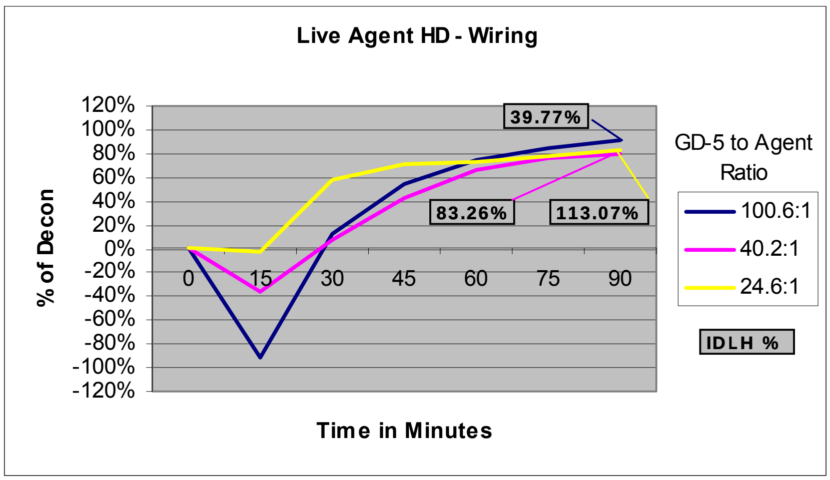

Figure B-3. Aerosolized GD-5 Decontamination Effectiveness Against HD on Wiring.

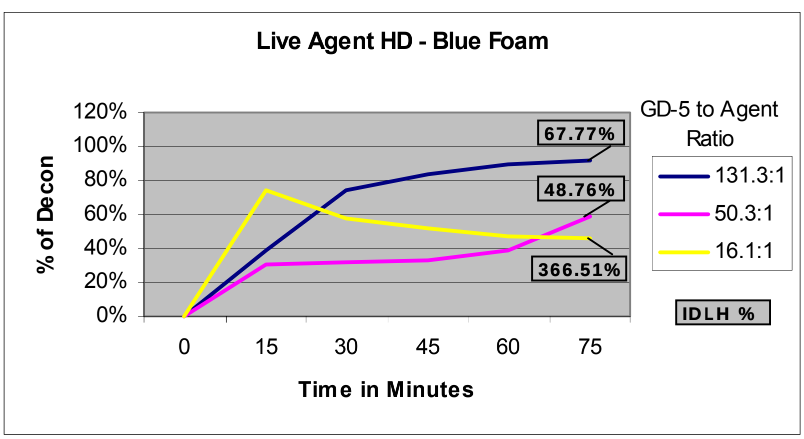

Figure B-4. Aerosolized GD-5 Decontamination Effectiveness Against HD on Blue Foam.

Figure B-5 shows Hapsite data collected on GF as a confidence check on a G agent that is similar to the agent GD (GF was not used during subsequent evaluations in this FCT).

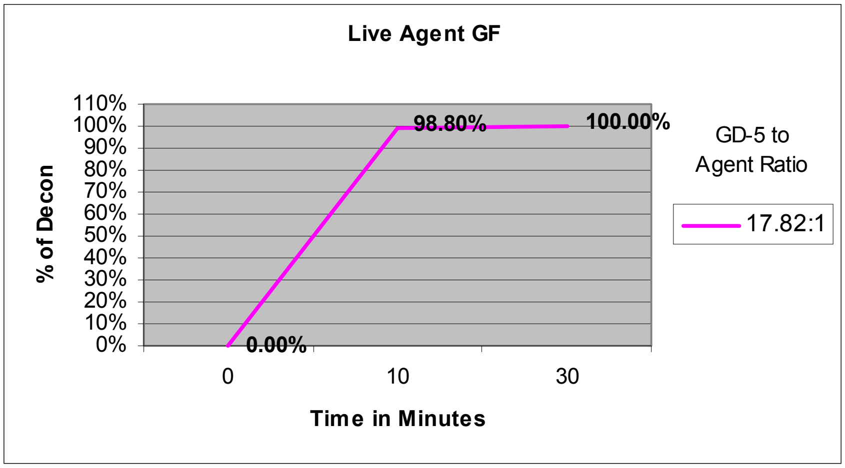

Figure B-5. Hapsite Data, Aerosolized GD-5 Decontamination Effectivess Against GF.

Figure B-6 shows ratio and agents tested during the liquid phase testing using the Hapsite.

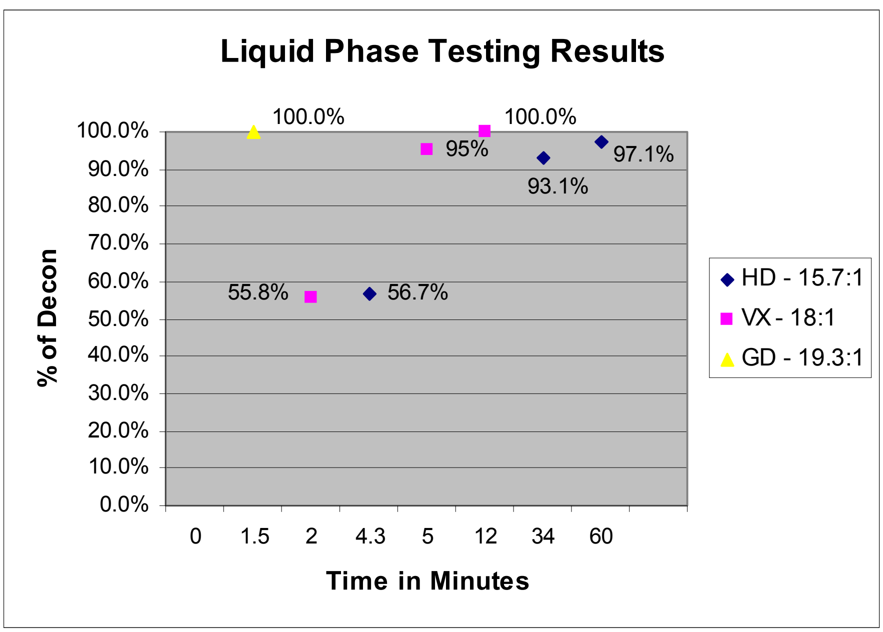

Figure B-6. Liquid Phase Test Results.

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APPENDIX C
CORROSION TEST RESULTS

Table C-1 depicts the overall ratings assigned to each MOE relating to the corrosion testing portion of the FCT. These results, along with the results from the other portions of the FCT, were then aggregated to establish the overall rating for each task

Table C-1. Corrosion Testing MOE Ratings.

MOE 2.1	▲	Percentage of time that GD-5 does not impact sensitive equipment.
MOE 2.2	▲	Percentage of time that GD-5 does not corrode aircraft materials.
MOE 2.3	▲	Percentage of time that GD-5 remains on sensitive equipment for 180 minutes.
MOE 2.4	▲	Percentage of time that GD-5 remains on aircraft materials for 180 minutes.
MOE 2.5	△	Characteristics of GD-5 decontaminant solution.
MOE 3.3	▲	Representative user rating of the applicator's capabilities to accomplish decontamination.
MOE 3.4	▲	Representative user ratings of the applicator's dependability (or tendency to experience mission-impacting failures).
MOE 3.5	▲	Representative user ratings of the GD-5 decontamination system's sustainability.

▲ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities

ASTM Standard G1-90 was used to determine the average corrosion rate of the coupons after being exposed to GD-5. Corrosion rates are expressed in mils per year in Figure C-1. According to the NACE Standard TM 169-76, a benchmark of 2.0 mils per year is considered excellent.

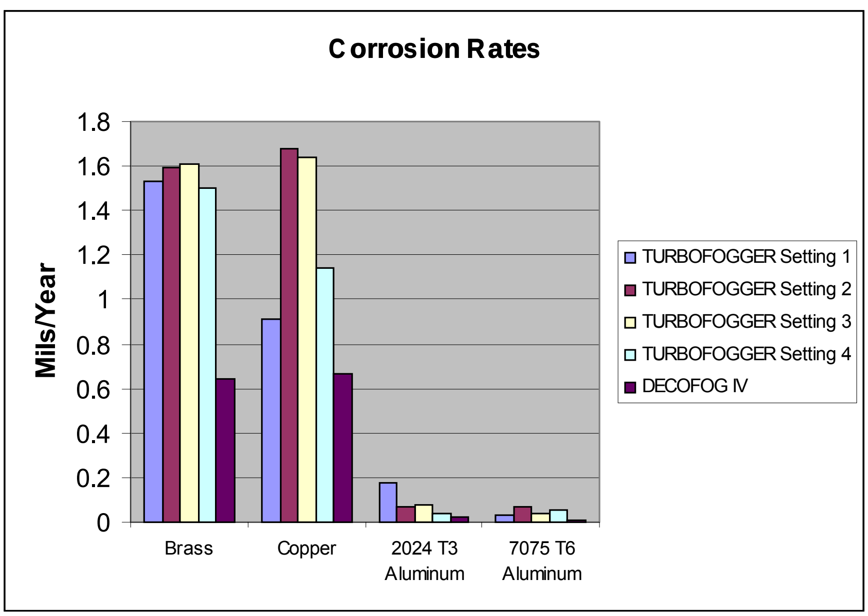

Figure C-1. Average Corrosion Rates.

During the corrosion testing, observations were made of each material tested with GD-5. Table C-2 shows observations made throughout the corrosion test process.

Table C-2. Coupon Observations.

72 hour exposure time, coupons washed in accordance with ASTM Standard G 31-72		
Applicator	**Material**	**Observations**
TURBO-FOGGER Setting 1	Brass	Blue/red discoloration, tarnished
	Copper	Yellow/red discoloration, tarnished
	Acrylic	No visible change
	2024 T3 Aluminum	Mottled mudcake scale, surface etching
	2024 T3 Anodized Aluminum	Very slight yellowing of coupon color
	2024 T3 Alodined Aluminum	Alodine coating completely removed on about 25% of coupon, coating remaining - faded gold color with blue/red discoloration in some areas.
	2024 T3 Alodine, Primed, Painted	Very slight graying of the white paint.
	7075 T6 Aluminum	Very slight tarnishing
	7075 T6 Alodined Aluminum	Alodine coating partially removed, coating remaining faded gold color.
	7075 Alodined, Primed Aluminum	No observable change.
TURBO-FOGGER Setting 2	Brass	Severe discoloration, heavily tarnished
	Copper	Severe discoloration – rust, blue and yellow, tarnishing, very slight pitting
	Acrylic	No observable change
	2024 T3 Aluminum	Mottled mudcake scale, surface etching
	2024 T3 Anodized Aluminum	No observable change
	2024 T3 Alodined Aluminum	Alodine coating completely removed on about 5% of coupon, coating remaining - faded gold color with blue/red discoloration in some areas.
	2024 T3 Alodine, Primed, Painted Aluminum	Dulling of paint surface where GD-5 beaded. Etching of paint spray pattern.
	7075 T6 Aluminum	No observable change
	7075 T6 Alodined Aluminum	Alodine coating 90% removed
	7075 Alodined, Primed Aluminum	Grey spots where GD-5 beaded on coupon.
TURBO-FOGGER Setting 3	Brass	Discoloration– blue/yellow, heavily tarnished
	Copper	Discoloration – blue/yellow/rust, tarnishing
	Acrylic	No observable change
	2024 T3 Aluminum	Mottled mudcake scale, surface etching
	2024 T3 Anodized Aluminum	No observable change
	2024 T3 Alodined Aluminum	Alodine coating faded, some areas with green/red discoloration.
	2024 T3 Alodine, Primed, Painted Aluminum	Dulling of paint surface where GD-5 beaded. Etching of paint spray pattern.
	7075 T6 Aluminum	Very slight tarnishing
	7075 T6 Alodined Aluminum	Alodine coating completely removed except in area of clip.
	7075 Alodined, Primed Aluminum	Some discoloration

Table C-2 (continued)

TURBO-FOGGER Setting 4	Brass	Severe discoloration–blue/yellow, heavily tarnished
	Copper	Severe discoloration- blue/yellow/rust, tarnishing
	Acrylic	No observable change
	2024 T3 Aluminum	Mottled mudcake scale, surface etching
	2024 T3 Anodized Aluminum	No observable change
	2024 T3 Alodined Aluminum	Some of the alodine coating removed
	2024 T3 Alodine, Primed, Painted Aluminum	Etching of the paint spray pattern
	7075 T6 Aluminum	Some discoloration
	7075 T6 Alodined Aluminum	Majority of alodine coating removed
	7075 Alodined, Primed Aluminum	Some discoloration
DECOFOG IV	Brass	Some pitting.
	Copper	Some surface etch pitting - microscopic
	Acrylic	No observable change
	2024 T3 Aluminum	Some loss of luster
	2024 T3 Anodized Aluminum	No observable change
	2024 T3 Alodined Aluminum	Some dissolution of the chromium coat
	2024 T3 Alodine, Primed, Painted Aluminum	Etching of the paint spray pattern
	7075 T6 Aluminum	Some loss of luster
	7075 T6 Alodined Aluminum	Complete dissolution of chromium coat
	7075 Alodined, Primed Aluminum	Some etching of primed surface.

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APPENDIX D
MILITARY UTILITY ASSESSMENT

Table D-1 depicts the overall ratings assigned to each MOE relating to the field demonstration portion of the FCT.

Table D-1. Field Demonstration MOE Ratings.

MOE 1.1	△	Effectiveness of GD-5 in decontaminating the chemical agents (or simulants).
MOE 2.1	▲	Percentage of time that GD-5 does not impact sensitive equipment.
MOE 2.2	▲	Percentage of time that GD-5 does not corrode aircraft materials.
MOE 2.3	▲	Percentage of time that GD-5 remains on sensitive equipment for 180 minutes.
MOE 2.4	▲	Percentage of time that GD-5 remains on aircraft materials for 180 minutes.
MOE 2.5	△	Characteristics of GD-5 decontaminant solution.
MOE 3.1	△	Percentage of trials where GD-5 fogging decontaminates chemical simulant in LFA interiors and cargoes supporting mission requirements for ground operations.
MOE 3.2	△	Percentage of trails where GD-5 fogging decontaminates LFA interiors and cargoes supporting mission requirements in a flight mode.
MOE 3.3	▲	Representative user rating of the applicator's capabilities to accomplish decontamination.
MOE 3.4	▲	Representative user ratings of the applicator's dependability (or tendency to experience mission-impacting failures).
MOE 3.5	▲	Representative user ratings of the GD-5 decontamination system's sustainability.

▲ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities

These results, along with the results from the other portions of the FCT, were then aggregated to establish the overall rating for each task.

Figure D-1 shows the high level concentrations achieved and the related temperature and humidity at the time of the readings. Figure D-2 shows the DHP-100 level reading achieved between the start of each test event and high level achieved during each event in ppm. Figure D-3 is the difference between the start of each test event and high level achieved during each event in mg/m3.

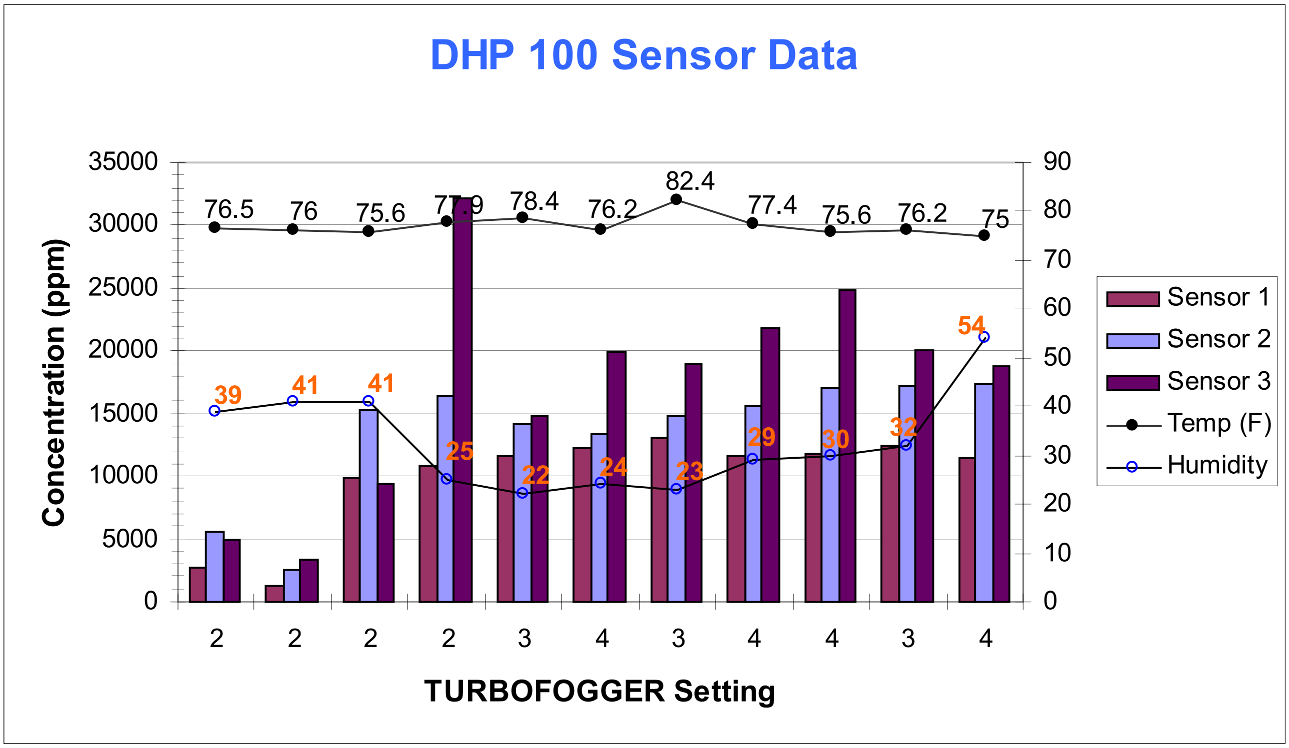

Figure D-1. DHP-100 Concentration Level Readings.

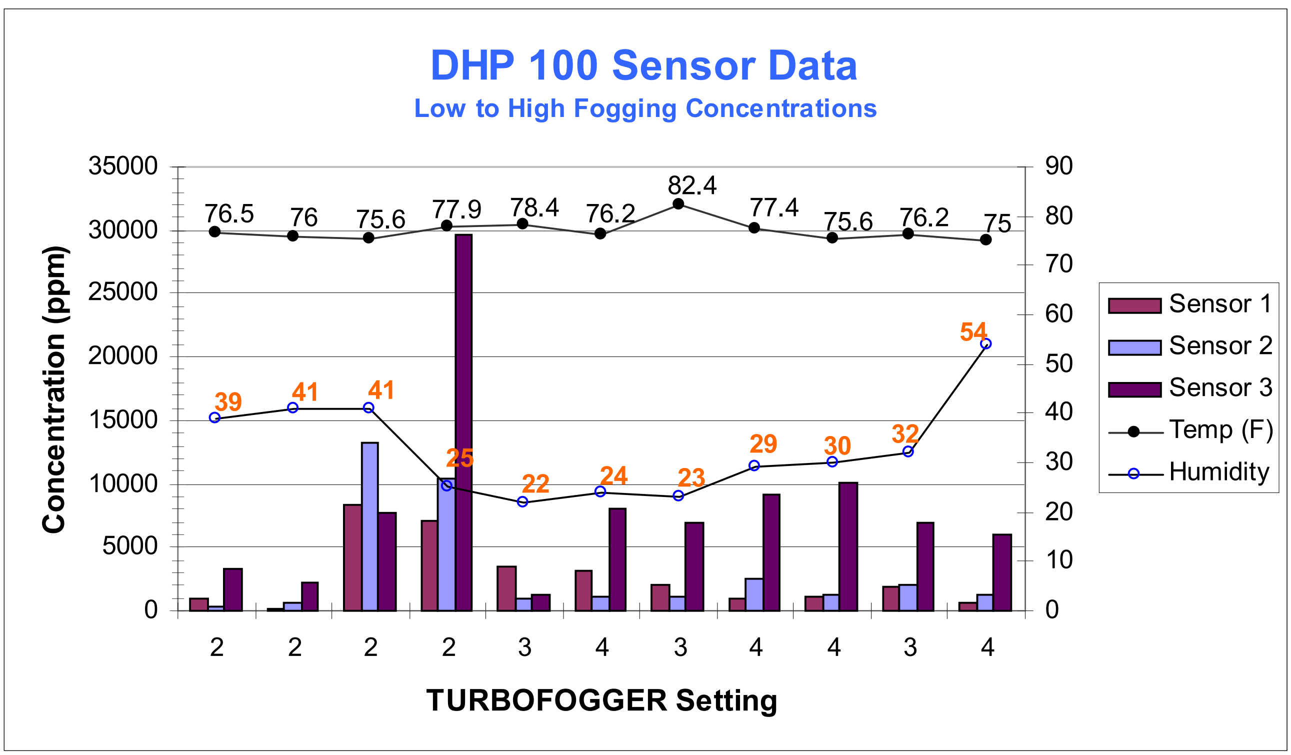

Figure D-2. DHP-100 Concentration Levels.

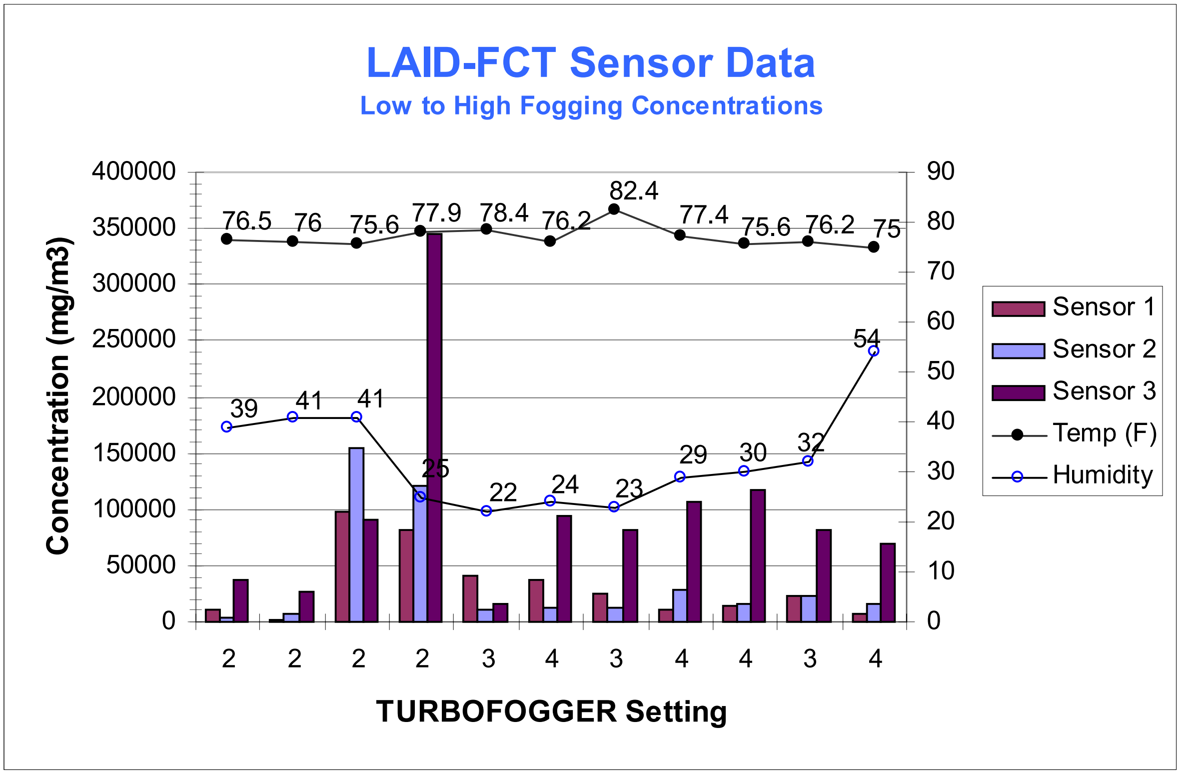

Figure D-3. DHP-100 Concentration Levels.

Users from both the corrosion test and field demonstration felt that the TURBOFOGGER applicator was easily prepared for decontamination operations as is evident by Figure D-4.

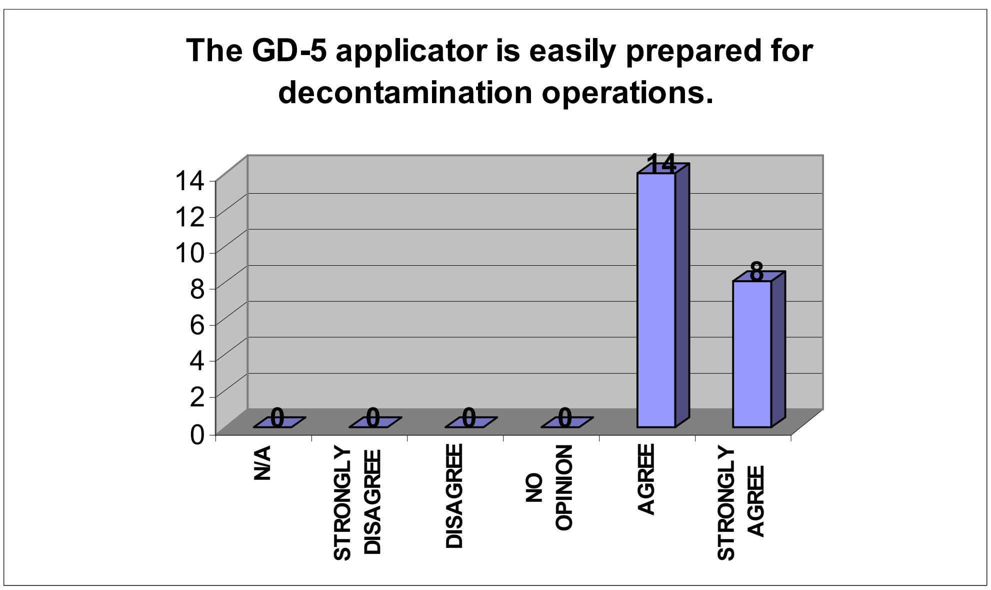

Figure D-4. Users' Opinion on Ease of TURBOFOGGER and GD-5 Preparation.

Figure D-5 shows the users opinion of the TURBOFOGGER's switch setting (fog tap). Although many users disagreed that it could support decontamination operations, they also recommended adding a detent in order to correct the problem.

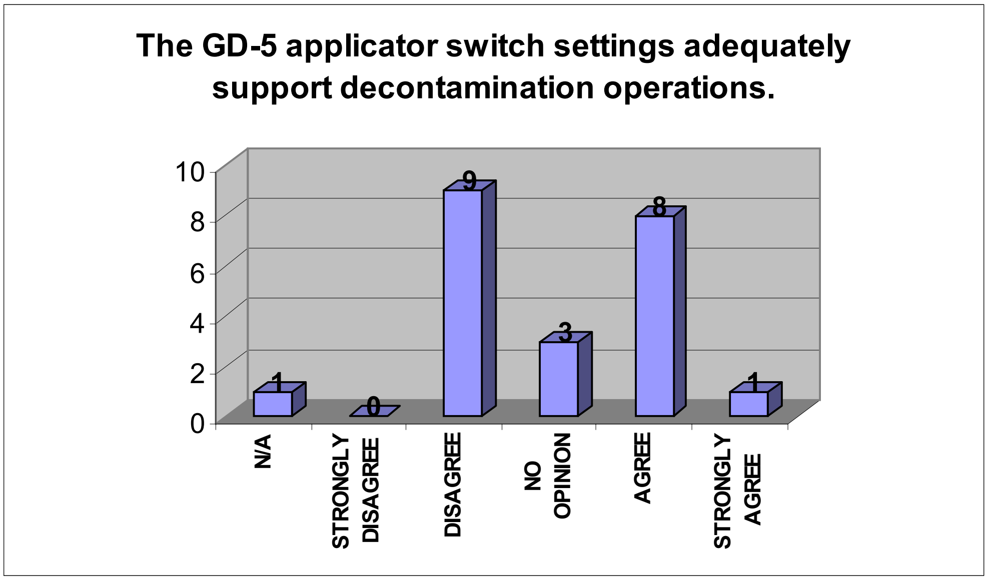

Figure D-5. Users' Opinion of the TURBOFOGGER Switch Settings.

APPENDIX E
VENDOR CLAIMS

For
The GD-5 Solution, DECOFOG IV and TURBOFOGGER Applicators

Claims Statements from Product Brochures
Internet Information (http://www.owr.de/seite11.html, 21 June 2000)

NOTES: *1. All performance parameters (capabilities and their associated criteria) assessed during this FCT are linked to task accomplishment by MOEs.*
2. I/D denotes insufficient data for a conclusive rating.

Ref ID	System Capability or Characteristic	Criteria or Performance Level Claimed by Vendor	MOE	Remarks	FCT Results
System Performance					
A	DECONTAMINATE INTERIOR SURFACES AND CARGO (neutralize effects of all chemical agents present on interior surfaces and cargo)	Useful for all known chemical warfare agents (www.owr.de/seite11.html)	1.1, 1.2	Laboratory test to verify selected live agent/simulant neutralization	
AA		May be used for vehicle interiors, including aircraft (www.owr.de/seite11.html)	1.1, 1.2	Field Demonstration to verify aircraft decontamination	
C	TIME TO DECONTAMINATE IN-FLIGHT	Reaction time for neutralization is 10 to 20 minutes (Brochure)	3.2	Aircraft pressurized on ground to simulate flight mode	
G	ADVERSE EFFECTS ON AIRCRAFT SYSTEMS OR SURFACES (examples of systems include environmental control, fire control, and communications, among others)	Non-corrosive (www.owr.de/seite11.html)	2.1, 2.2 2.1, 2.2	• Laboratory test to quantify corrosive effects • Field demonstration to document observable effects on aircraft & cargo	
GA		Allows decontamination of sensitive electronic equipment (Brochure)	2.1	Laboratory test to examine deleterious effects of GD-5	

Ref ID	System Capability or Characteristic	Criteria or Performance Level Claimed by Vendor	MOE	Remarks	FCT Results
		GD-5 Decontaminant			
J	NEUTRALIZE ALL CHEMICAL AGENTS (Liquid Phase Test)	Useful for all known chemical agents (www.owr.de/seite11.html)	1.1, 1.2	This FCT sought to verify neutralization of GD, HD, and VX only	
K	RESIDUE/VAPOR PRODUCTION (includes decontaminant and by-products of decontaminant interaction with agents)	GD-5 is environmentally safe (Brochure)	2.5	Based on Materials Safety Data Sheet	
KA		Non-corrosive (www.owr.de/seite11.html)	2.1, 2.2 2.1, 2.2	• Laboratory test to quantify corrosive effects • Field demonstration to document observable effects on aircraft & cargo	
KB		Brush off dry residue, no other clean up required (Brochure)	2.5 2.5	• Includes determination of time required for dispensed GD-5 to dry to residue (prior to disposal) • Disposability based on chemical makeup and U.S. environ-mental compliance	I/D
N	ENVIRONMENTAL HAZARD (examples of current decontaminants include DS-2, Super Tropical Bleach, and Hypoclorite)	GD-5 is environmentally safe (Brochure)	2.5	Based on Materials Safety Data Sheet	
P	LIQUID CHARACTERISTIC	Non-aqueous (Brochure)	2.5		

Ref ID	System Capability or Characteristic	Criteria or Performance Level Claimed by Vendor	MOE	Remarks	FCT Results
		DECOFOG IV Applicator			
S	SIZE	106 x 29 x 33 cm (41.7 x 11.4 x 13 in) (www.owr.de/seite11.html)	3.3		▲
T	WEIGHT	7 kg (15.5 lbs) (www.owr.de/seite11.html)	3.3		▲
U	TRANSPORTABILITY	Light and transportable (Brochure)	3.4, 3.5	Based on field observations and user inputs	▲
		TURBOFOGGER Applicator			
W	CONTINUOUS OPERATION WITHOUT RESUPPLY	30 minutes (maximum) [based on 5 l detachable tank and a minimum application rate of 10 l/hr] (www.owr.de/seite11.html)	3.3		▲
WA		Adjustable atomization or flow rate (Brochure)	3.3		◭
X	SIZE	87 x 18 x 27 cm (Brochure)	3.3		▲
Y	WEIGHT	6.9 kg (15.4 lbs) (Brochure)	3.3		▲
YA	TRANSPORTABILITY	Small and handy (Brochure)	3.5	Based on field observations and user inputs	▲
Z	POWER SOURCE	Plug-in electrical power (1.0 kW@4.6 amps on 220 volt power) [custom configurations available] (Brochure)	3.3	Based on field observations and user inputs	▼

▲ – Demonstrated utility
◭ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities
▼ – Potential utility; not deployable now; significant improvements required
I/D – Insufficient data for a conclusive rating

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APPENDIX F
OPERATIONAL REQUIREMENTS SUMMATION MATRIX

For
LAID-FCT

Requirement Statements As Published in the LAID-FCT Assessment Execution Document
Requirements Correlation Matrix (RCM) Developed By Det 1 from
JSSED ORD, 17 Aug 1999

NOTES: *1. All performance parameters (capabilities and their associated criteria) assessed during this FCT are linked to task accomplishment by MOEs.*
2. I/D denotes insufficient data for a conclusive rating.

RCM Ref #	System Capability or Characteristic	Criteria Threshold	MOE	Remarks	FCT Rating
*1	DECONTAMINATE INTERIOR SURFACES AND CARGO (neutralize effects of all chemical agents present on interior surfaces and cargo)	On Ground	1.1, 1.2	• Laboratory test to verify live agent, simulant neutralization	△
			1.1, 1.2	• Liquid	▲
			1.1, 1.2	• Aerosol	△
			1.1, 1.2	• Field demonstration to verify aircraft decontamination	I/D
2		In-flight	1.1, 1.2	Field demonstration to verify aircraft decontamination	I/D
7	TIME TO DECONTAMINATE IN-FLIGHT	1 Hour (C-17 Interior Equivalent)	3.2	Aircraft pressurized on ground to simulate flight mode	△
8	STORAGE	On-board Aircraft	3.5	Based on field observations and user inputs	▲
9		Securable	3.5	Based on field observations and user inputs	▲
10	READINESS	No Decontaminant Processing	3.3	Based on field observations and user inputs	▲
11		No Decontaminant Testing	3.3	Based on field observations and user inputs	▲

RCM Ref #	System Capability or Characteristic	Criteria Threshold	MOE	Remarks	FCT Rating
14	VULNERABILITY TO OPERATIONAL ENVIRONMENTAL CONDITIONS (Includes, but is not limited to, corrosion, vibration, dust, smoke, fungus, fuels, salt water spray/fog, and space restrictions for operations)	Perform Mission Essential Functions	3.3	**COMMENT ONLY** (based on field observations and user inputs)	▲
20	VULNERABILITY TO OPERATIONAL HAZARDS (hazards include rapid decompression, lightning, turbulence, droppage)	Perform Mission Essential Functions	3.3	**COMMENT ONLY** (based on field observations and user inputs)	I/D
24	ADVERSE EFFECTS ON AIRCRAFT SYSTEMS OR SURFACES (examples of systems include environmental control, fire control, and communications, among others)	None	2.1, 2.2 2.1, 2.2	• Laboratory test to quantify corrosive effects • Field demonstration to document observable effects on aircraft & cargo	▲ ▲
36	NEUTRALIZE ALL CHEMICAL AGENTS (on interior surfaces, including sensitive equipment such as electronics and materials other than metal, and cargo)	Safe Level for Unrestricted Operations**	1.1, 1.2	GD, HD, and VX, and the simulants DEM and MES	△
37	RESIDUE/VAPOR PRODUCTION (includes decontaminant and by-products of decontaminant interaction with agents)	Non-toxic	2.5	Based on Materials Safety Data Sheet	△
38		Non-corrosive	2.1, 2.2 2.1, 2.2	• Laboratory test to quantify corrosive effects • Field demonstration to document observable effects on aircraft & cargo	▲ ▲

RCM Ref #	System Capability or Characteristic	Criteria Threshold	MOE	Remarks	FCT Rating
39		Disposable	2.5 2.5	• Includes determination of time required for dispensed GD-5 to dry to residue (prior to disposal) • Disposability based on chemical makeup and U.S. environ-mental compliance	I/D
40	ENVIRONMENTAL HAZARD (examples of current decontaminants include DS-2, Super Tropical Bleach and Hypoclorite)	Less Hazardous Than Current Decontaminants	2.5	Based on OSHA Materials Safety Data Sheet	
42	LIQUID CHARACTERISTIC	Non-aqueous	2.5	Based on Materials Safety Data Sheet	
43	DISPOSIBILITY [not specified if this applies to decontaminant post application and/or before use (as in spillage or when disposing of out-dated material)]	Biodegradable	2.5	Comments Based On Laboratory Results	
44	FLAMMABILITY	Non-flammable	2.5		I/D
45	DISCHARGE LINE LENGTH	Reach Throughout Aircraft	3.3		
46	CONTINOUS OPERATION WITHOUT RESUPPLY	1 Hour	3.3		
47	SIZE	Fit In Crew Entrance Door	3.3		
48	WEIGHT	100 Pounds	3.3		
49	TRANSPORTABILITY	Man-portable	3.5	Based on field observations and user inputs	
50	ALLOWABLE ERGONOMIC HAZARDS	None	3.5	Based on field observations and user inputs	
51	DESIGN	Modular	3.3	Based on field observations and user inputs	
53	POWER SOURCE	Compatible With Standard Internal/ External Systems	3.3	Based on field observations and user inputs	

RCM Ref #	System Capability or Characteristic	Criteria Threshold	MOE	Remarks	FCT Rating
56	REFILLING/RECHARG-ING WITH DECONTAMINANT	Easily Done	3.3	Based on field observations and user inputs	▲
57	ALLOWABLE HAZARDS DURING SERVICING	None	3.5	Based on field observations and user inputs	I/D
58	ALLOWABLE HAZARDS DURING OPERATION	None	3.5	Based on field observations and user inputs	I/D
59	ALLOWABLE HAZARDS DURING OPERATION IN MOPP GEAR	None	3.3	**COMMENT ONLY** (based on field observations and user inputs)	I/D

* Denotes Key Performance Parameter (KPP)

** A “safe or operational level” of chemical agent neutralization for “unrestricted operations” is defined as reduction in the concentration or neutralization of the effects of a chemical agent present on resources to below miosis or incapacitation levels [Joint Operational Requirements Document for Joint Service Fixed-site Decontamination System, Paragraph 4.a.(1)(a)].

▲ – Demonstrated utility
▲ – Demonstrated utility; improvements recommended
△ – No utility beyond currently fielded capabilities
▼ – Potential utility; not deployable now; significant improvements required
I/D – Insufficient data for a conclusive rating


AIR MOBILITY COMMAND